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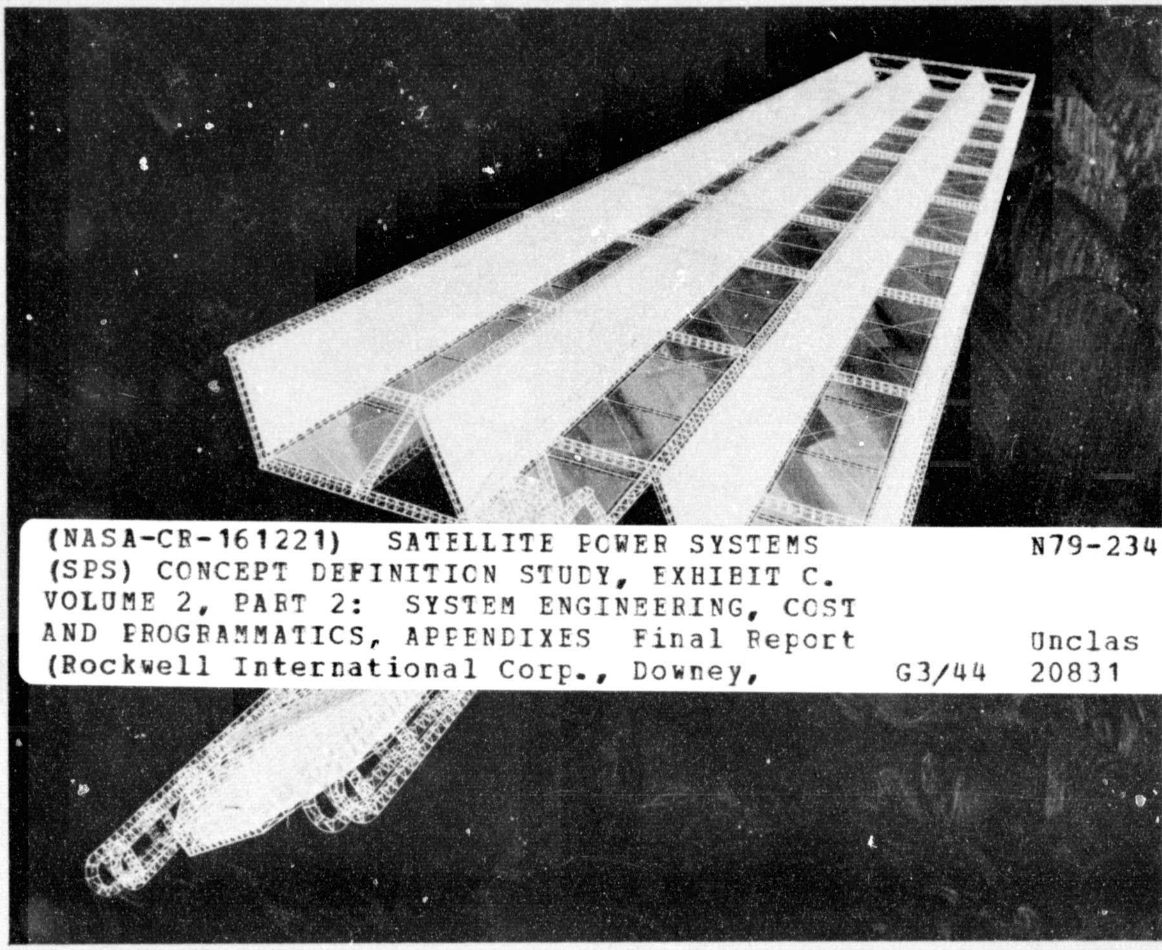

(NASA-CR-161221) SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY, EXHIBIT C. VOLUME 2, PART 2: SYSTEM ENGINEERING, COST AND PROGRAMMATICS, APPENDIXES Final Report (Rockwell International Corp., Downey, N79-23487 Unclas G3/44 20831

Satellite Power Systems (SPS) Concept Definition Study

FINAL REPORT (EXHIBIT C)

VOLUME II

SYSTEM ENGINEERING

PART 2

(COST AND PROGRAMMATICS – APPENDIXES)

Rockwell International

Satellite Systems Division
Space Systems Group

12214 Lakewood Boulevard
Downey, CA 90241

SSD 79-0010-2-2

Satellite Power Systems (SPS) Concept Definition Study

FINAL REPORT (EXHIBIT C)

VOLUME II

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(COST AND PROGRAMMATICS – APPENDIXES)

CONTRACT NAS8-32475
DPD 558 MA-04

March 1979

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FOREWORD

Volume II, System Engineering, is presented in two parts. Part 1 encompasses SPS system engineering aspects. Part 2 consists of a volume on SPS cost and programmatics; an appendix is included in Part 2 to cover the SPS WBS and cost estimates. Volume II of the SPS Concept Definition Study final report is submitted by Rockwell International through the Satellite Systems Division. All work was completed in response to NASA/MSFC Contract NAS8-32475, Exhibit C, dated March 28, 1978.

The SPS final report will provide the NASA with additional information on the selection of a viable SPS concept, and will furnish a basis for subsequent technology advancement and verification activities. Other volumes of the final report are listed as follows:

Volume	Title
I	Executive Summary
III	Experimentation/Verification Element Definition
IV	Transportation Analyses
V	Special-Emphasis Studies
VI	In-Depth Element Investigations
VII	Systems/Subsystems Requirements Data Book

The SPS Program Manager, G. M. Hanley, may be contacted on any of the technical or management aspects of this report. He can be reached at 213/594-3911, Seal Beach, California.

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ACKNOWLEDGEMENTS

Since the publication of earlier Rockwell SPS cost, economic, and programmatic documentation—dating back to 1976—a continuing effort has been maintained to incorporate the latest program developments, expand the Rockwell SPS cost model; conduct comparative cost/economic analyses; prepare integrated schedules or networks; and define SPS program plans and resource requirements. The results of this work represent a professional contribution on the part of many individuals, where most of them have been with the SPS contract activity and supplementing company-sponsored efforts since the start of our effort. It is this contribution that requires acknowledgement.

The overall study activity was also supported by other business/industrial organizations and technical members of the SPS program team and their management, making it possible to reach the desired conclusions with the minimum of effort.

The Rockwell SPS program development team that contributed to the search, analyses, and results of this study are:

• Dr. L. R. Blue	Cost/Risk Programming
• W. Cooper	Cost Analysis
• D. E. Lundin	SPS Schedules/Networks
• A. D. Kazanowski	Resource Analysis

The overall SPS program development activity on SPS costs, schedules, program planning, resource analysis, and computer programming was completed under the direction of F. W. Von Flue.

The help and support of personnel from NASA/MSFC and the SPS Program Planning Office is also acknowledged.

- Engineering Cost Group
  - W. S. Rutledge
  - J. W. Hamaker
  - D. T. Taylor
- Program Plans and Requirements Group
  - W. A. Ferguson
  - H. K. Turner

APPENDIX A

SATELLITE POWER SYSTEM WORK BREAKDOWN STRUCTURE DICTIONARY

SOLAR PHOTOVOLTAIC GaAlAs
CONCENTRATION RATIO (CR) - 2
THREE-TROUGH COPLANAR
END-MOUNTED ANTENNA

APPENDIX A
SATELLITE POWER SYSTEM WORK BREAKDOWN STRUCTURE DICTIONARY

INTRODUCTION

Generally a work breakdown structure (WBS) is thought to be a product-oriented family tree composed of all the hardware, software, services, and other tasks necessary to define the program. It offers visual display, relates project elements, and defines the work to be accomplished. The WBS is then a tool for facilitating communications and understanding a complex program by dividing this program into less complex, more manageable subdivisions or elements. It is most desirable that the WBS provide a uniform basis for management and control; cost estimating, budgeting and reporting; scheduling activities, organizational structuring, specification tree generation, weight allocation and control, procurement and contracting activities, and serve as a tool for program evaluation. Therefore, the WBS developed and defined herein is primarily tailored to the unique cost, economic, and programmatic requirements of the Satellite Power System (SPS). It is designed to allow a standard and logical format for estimating SPS project cost, while at the same time permitting cost and economic comparisons of SPS to alternate and competitive candidates for producing power.

WBS MATRIX

The total WBS matrix shown in Figure A-1 is a three-dimensional structure that shows the interrelationship of (1) the hardware and activities dimension, (2) the accounts and phases dimension, and (3) the elements of cost dimension. This latter dimension is not further developed at this time, but is provided to show the overall expansion capability built into the WBS matrix. This dimension will become more important in later years when the SPS program approaches a Phase C/D start and is defined to the extent that the elements of cost can be planned and estimated with realism.

There is, of course, the fourth dimension of time which cannot be graphically shown but must be considered also. Each entry on the other three dimensions varies with time, and it is necessary to know these cost values by year for budget planning and approval, and to establish cost streams for discounting purposes.

While a multiple-dimensional approach may at first appear unduly complex, it actually provides benefits that far outweigh any such concern. This structural interrelationship provides the capability to view and analyze the SPS from a number of different financial and management aspects. Costs may be summed by hardware groupings, phases, functions, etc. The WBS may be used in a number of three-dimensional, two-dimensional, or single-listing format applications.

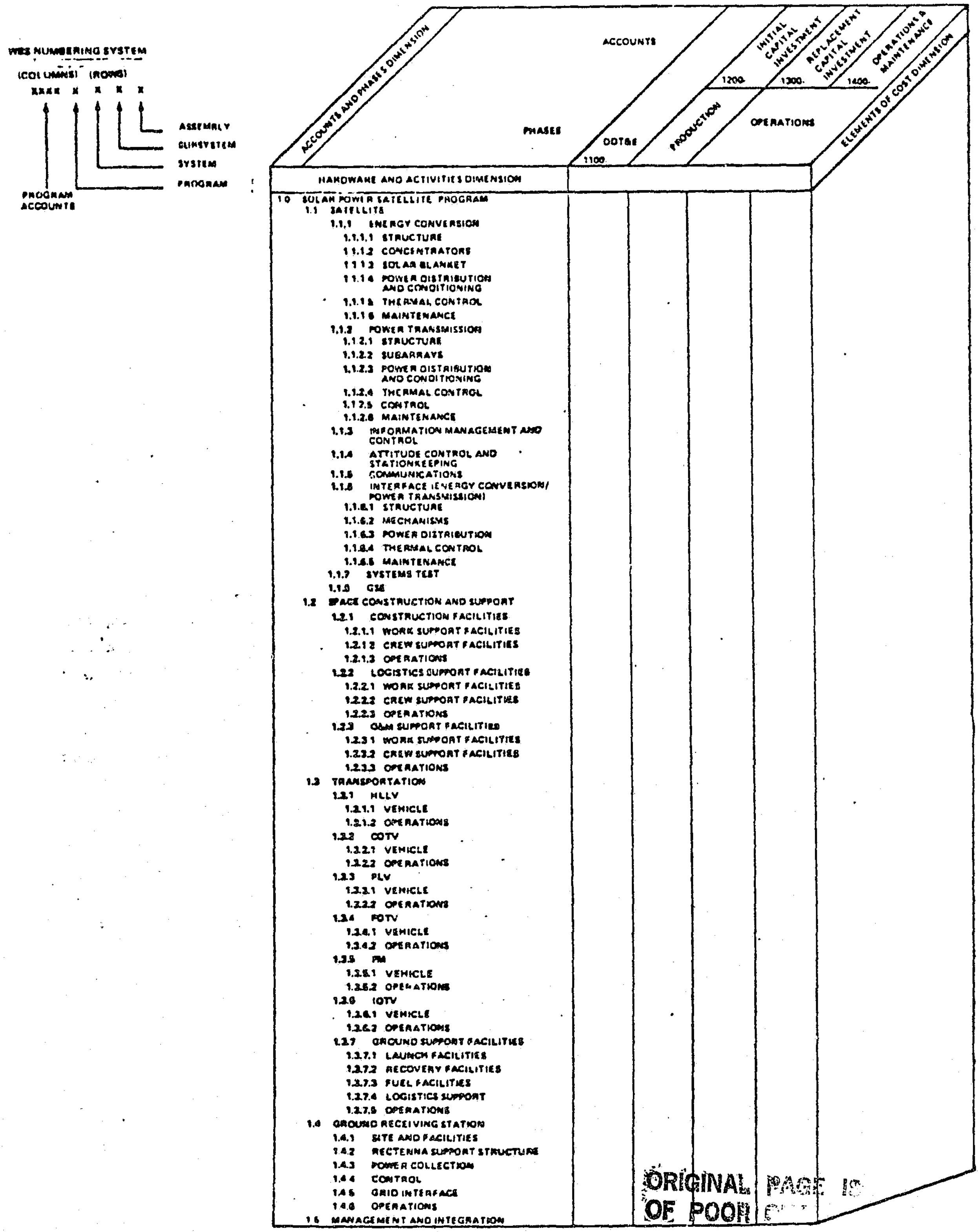

Figure A-1. Satellite Power System Work Breakdown Structure

ACCOUNTS AND PHASES DIMENSION

The accounts and phases dimension differs somewhat from the typical breakout for government aerospace programs in that it has been developed to also accommodate the financial involvement of the private sector, hence, the inclusion of the breakout of financial divisions or "accounts." Distinctions have been made between capital expenditures, which are recoverable by annual depreciation charges and are not deductible as expenses, and operation and maintenance charges against income, which are deductible as expenses in the year incurred.

To accomplish this objective, four financial accounts have been established. Design, development, test, and evaluation (DDT&E) includes the one-time costs associated with the development of components, subsystems, and systems required for the SPS project. Initial capital investment includes the costs associated with initial procurement and emplacement of the SPS plant and equipment. Replacement capital investment includes the costs associated with capital asset replacements over the operating life of the SPS (e.g., subsystem spare parts, overhauls, etc.). Operations and maintenance (O&M) includes the costs of expendables (e.g., propellants for the propulsion subsystem thrusters), minor maintenance, repair crews, etc. The interrelationship of the financial accounts to the normal aerospace program phases of DDT&E, investment, and operations are also shown in this dimension of the WBS matrix to permit traceability to these more commonly recognized therms.

HARDWARE AND ACTIVITIES WBS DIMENSION

The hardware and activities WBS dimension contains hardware elements of the satellite system and ground system subdivided into subsystems and assemblies. Inherent within this dimension is the capability for further subdivision to lower levels of detail limited only by the realism of the requirements.

Required support hardware, possibly developed under the sponsorship of other programs, is also displayed here for completeness and includes such items as space construction and support equipment and transportation vehicles. Some or all of these support elements may be developed for multiple project applications. A determination will be made later as to how much, if any, of the development costs of these support elements should be charged against the SPS program.

Each of the elements of support hardware is broken out only at a summary level within the SPS WBS. However, they each have their own detailed WBS which could be displayed in depth under the SPS WBS if required.

Finally, the hardware and activities WBS dimension also includes the necessary activities of management, integration, operations, etc., required to accomplish the overall SPS missions.

DICTIONARY ORGANIZATION

The SPS dictionary is divided into:

(1) A graphic display of the three-dimensional WBS matrix (Figure A-1)

(2) The definitions of terms of the accounts and phases dimension (pages A-5 and A-6)

(3) The definitions of terms of the WBS hardware and activities dimension (pages A-7 through A-16)

A systematic numerical coding system coordinates the rows of the hardware and activities dimension to the columns of the accounts and phases dimension such that all matrix locations are identifiable by WBS number.

Since each matrix position corresponds to one particular row of the hardware and activities dimension and also to one particular column of the accounts and phases dimension, a complete definition of any matrix position is constructed by combining the definitions from the two applicable dimensions. That is, to avoid repetition, definitions are provided only once for each hardware and activities dimension row and only once for each accounts and phases dimension column, and a complete definition for any matrix position is a combination of these two definitions.

DEFINITIONS OF ACCOUNTS AND PHASES

1100—DESIGN, DEVELOPMENT, TEST, AND EVALUATION (DDT&E)

The DDT&E account/phase consists of the one-time costs associated with designing, developing, testing, and evaluating the components, subsystems, and systems required for the SPS project. It includes the development engineering, testing, and support necessary to translate a performance specification into a design. It encompasses the preparation of detailed drawings for system hardware fabrication, system integration, and (depending on the system, subsystem, or component) structural, environmental, and other required tests. It includes all ground tests, sortie tests, subscale and full-scale SPS tests, and all hardware fabrication required for such tests. Also included are the analysis of data and whatever redesign and retest activities are necessary to meet specifications. It also includes ground support equipment, special test equipment, and other program-peculiar costs not associated with repetitive production. All SPS related support systems such as transportation, space construction base, and assembly/support equipment necessary to accomplish the DDT&E phase are included at present for completeness. It may later be determined that some of these support systems will exist with or without SPS; therefore, they may not be chargeable to the SPS project.

1200—INITIAL CAPITAL INVESTMENT

The initial capital investment account is a summation of those plant and equipment expenditures made for the initial procurement and installation of each full-scale SPS. That is, this account collects the production, assembly, installation, transportation, test, etc., costs of each individual satellite and ground station that is associated with, and necessary to, bringing the power plant on-line (in government aerospace terminology, this corresponds to costs in the investment phase). Examples of costs collected in this account are the procurement cost and launch cost of the satellite system itself, the procurement cost of the ground system (including installation), and all other necessary costs to achieve this end such as those attributable to space stations, launch vehicle fleets, etc. Also included is pro rata share of such functional costs as program management, SE&I, etc., related to the foregoing systems. Only costs incurred after the end of the DDT&E phase and prior to the initial operational capability (IOC) of each SPS are collected in this account.

1300—REPLACEMENT CAPITAL INVESTMENT

The replacement capital investment account is a summation of those plant and equipment expenditures made for capital asset replacement and major overhauls that are expected to last more than one year and result in an improvement to the operating system. Examples of costs collected in this account are the costs of spares, their installation and associated launch costs or ground transportation costs, permanent improvements in the system such as rotary joint replacement, installation of improved design satellite control equipment, etc.,

as well as pro rata shares of functional costs. These expenditures begin at the IOC and continue over the life of each SPS.

1400—OPERATIONS AND MAINTENANCE (O&M)

The O&M account is a summation of those expenditures incurred in the day-to-day operations beginning with the IOC and continuing over the life of each SPS. Examples of costs collected in this account are wages of operations and maintenance personnel, minor repairs and adjustments to systems to maintain an ordinarily efficient operating condition, expendables and consumables, launch costs for transfer of on-orbit personnel and resupply of expendables and consumables, etc.

DEFINITIONS OF HARDWARE AND ACTIVITIES

1.0 SATELLITE POWER SYSTEM PROGRAM

The program includes all the elements of hardware, software, and activities required for the design, development, production, assembly, transportation, operations, and maintenance of the SPS program systems. Included are the satellite and ground receiving station systems, as well as the necessary support systems such as space construction and support and transportation.

1.1 SATELLITE

This element includes the hardware and software located in geosynchronous orbit (GEO) for the collection of solar energy, conversion to electrical energy, and transmission of electrical energy in microwave form to earth.

1.1.1 ENERGY CONVERSION

This element includes the components required to collect solar energy, convert the solar energy to electrical energy, condition the electrical energy, and transport it to the interface wubsystem (WBS No. 1.1.6).

1.1.1.1 STRUCTURE

This element includes all necessary members to support the concentrators, solar blankets, and other energy conversion subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures which are required as an interface between the primary structure and the mounting attach points of components, assemblies, and subsystems.

1.1.1.2 CONCENTRATORS

This element concentrates the solar energy onto the solar blanket to increase the energy density on the conversion device. It includes the reflective material and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

1.1.1.3 SOLAR BLANKET

This element converts solar energy to electrical energy and provides power to the power distribution and conditioning buses. It includes the photovoltaic conversion cells, coverplates, substrate, electrical interconnects, and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

1.1.1.4 POWER DISTRIBUTION AND CONDITIONING

This element includes the power conductors, switch gear, and conditioning equipment and slip rings required to transfer power from the solar blanket to the interface subsystem power distribution elements. Also included are electrical cables and harnesses required to distribute power to equipment located on

the energy conversion structure, plus batteries or storage medium for information system and attitude control. Excluded are data buses which are included in the information management and control subsystem (WBS No. 1.1.3).

1.1.1.5 THERMAL CONTROL

This element includes any component used to modify the temperature of the energy conversion subsystem components. It includes coldplates, heat transfer, and radiator devices, as well as insulation, thermal control coatings, and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence.

1.1.1.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

1.1.2 POWER TRANSMISSION

This element receives dc electrical power from the interface subsystem, conditions the power, converts it to microwave energy, and radiates the energy to the ground receiving station. Included are power distributions from the interface subsystem, dc-to-RF conversion devices, control and monitoring equipment, and antenna radiating elements.

1.1.2.1 STRUCTURE

This element includes all members necessary to support the transmitter subarrays and other power transmission subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures.

1.1.2.2 TRANSMITTER SUBARRAYS

This element includes all the hardware required for generation, distribution, phase control, and radiation of microwave energy. This includes the subarray structure, waveguides, power amplifiers, phase control electronics, and power harnesses. Also included are thermal control devices and finishes that are manufactured as an integral part of the subarray.

1.1.2.3 POWER DISTRIBUTION AND CONDITIONING

This element includes the power conductors, switch gear, and conditioning equipment required to transfer power from the interface subsystem to the subarray wiring harnesses and to any other power-consuming/storage equipment located on the power transmission structure, such as batteries.

1.1.2.4 THERMAL CONTROL

This element includes any component used to modify the temperature of power transmission subsystem components. It includes coldplates, heat transfer and radiator devices, as well as insulation, thermal control coatings, and finishes. Excluded are paints and finishes applied to components during their

manufacturing sequence and thermal control devices that are an integral part of another component.

1.1.2.5 CONTROL

This element provides the reference phase for all subarray phase conjugating circuits. This includes the reference oscillator signal distribution and frequency conversion equipment plus components that commonly serve all subarrays.

1.1.2.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

1.1.3 INFORMATION MANAGEMENT AND CONTROL

This element includes those components that process information on board the satellite. This includes sensing, signal conditioning, formatting, computations, formulation and signal routing.

1.1.4 ATTITUDE CONTROL AND STATIONKEEPING

This element includes the components required to orient and maintain the satellite's position and attitude in GEO. Included are sensors, reaction wheels, chemical and electric propulsion hardware, and propellants.

1.1.5 COMMUNICATIONS

This element includes the hardware to transmit and receive intelligence among the various SPS elements. This includes communication of both data and voice between the SPS and the control center, as well as among the various cargo and personnel vehicles. Excluded is intravehicular and intrasatellite communications.

1.1.6 INTERFACE (ENERGY CONVERSION/POWER TRANSMISSION)

This element provides the movable interface between the energy conversion subsystem and the power transmission subsystem. A 360° rotary joint and an antenna elevation mechanism are required to maintain proper alignment of the transmitter with the ground receiving station. Included are structure, mechanisms, power distribution, thermal control, and maintenance hardware.

1.1.6.1 STRUCTURE

This element includes all members necessary to provide a mechanical interface between the primary structures of the energy conversion subsystem and the power transmission subsystem. It includes beams, beam couplers, cables, tensioning devices, and secondary structures. Excluded are elements of the drive assembly which are included in mechanisms (WBS No. 1.1.6.2).

1.1.6.2 MECHANISMS

This element includes the components required to rotate and elevate the power transmission subsystem. Included are the drive ring, bearings, gear drives and drive motors.

1.1.6.3 POWER DISTRIBUTION

This element provides for the transfer of electrical power through the interface. It includes slip rings, brush assemblies, feeders, and insulation.

1.1.6.4 THERMAL CONTROL

This element includes any component used to modify the temperature of interface subsystem components. It includes coldplates, heat transfer and radiator devices, as well as insulation, thermal control coatings, and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence.

1.1.6.5 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

1.1.7 SYSTEMS TEST

This element includes the hardware, software, and activities required for ground-based systems tests including qualification tests and other development tests involving two or more subsystems or assemblies. It includes the production, assembly, integration, and checkout of satellite system hardware into a full or partial system test article. It also includes the design, development, and manufacture of special test equipment, test fixtures, and test facilities that are not included in other elements such as ground support faciliteis. Also included are the planning, documentation, and actual test operations.

1.1.8 GROUND SUPPORT EQUIPMENT (GSE)

This element includes all ground-based hardware required in support of handling, servicing, test, and checkout of the satellite subsystems. It also includes special hardware required for simulations and training.

1.1.9 PRECURSOR TEST ARTICLE

The precursor pilot plan test article and operations are included in this element. It represents a test vehicle that consists of an energy conversion, interface, and power transmission segment.

1.2 SPACE CONSTRUCTION AND SUPPORT

This element includes all hardware and activities required to assemble, check out, operate, and maintain the satellite system. Included are space stations, construction facilities, support facilities and equipment, and manpower operations.

1.2.1 CONSTRUCTION FACILITIES

This element includes the facilities, equipment, and operations required to assemble and check out the satellite system. Included are crew life support facilities, the central control facility, fabrication and assembly facilities, cargo depots, and operations.

1.2.1.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required for satellite assembly and checkout. Included are beam fabricators, manipulators, assembly jigs, installation and deployment equipment, and cargo storage depots. Excluded are the facilities related to crew support.

1.2.1.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, center control facilities, recreation facilities, and health facilities of the satellite construction base.

1.2.1.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the construction facility. It includes both the direct and support personnel and the expendable maintenance supplies required for satellite assembly and checkout.

1.2.2 LOGISTICS SUPPORT FACILITIES

This element includes the hardware, software, and operations required in low earth orbit (LEO) to support the construction and operations and maintenance of the satellite system. Included are crew life support facilities, cargo and propellant depots, and vehicle servicing facilities necessary for the receiving, storage, and transfer of cargo and personnel destined for a construction base or operational satellite located in GEO.

1.2.2.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required to provide logistics support in LEO. Included are heavy-lift launch vehicle (HLLV) and orbital transfer vehicle (OTV) docking stations, payload handling equipment, and cargo and propellant storage depots. Excluded are facilities related to crew support.

1.2.2.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities of the LEO Base.

1.2.2.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the logistics support facility. It includes both the direct and support personnel and the expendable maintenance supplies required for logistics support.

1.2.3 O&M SUPPORT FACILITIES

This element includes the facilities, equipment, and operations required in GEO to support the operations and maintenance of the satellite system. Included are the on-orbit monitor and control facility and the life support facilities and equipment required to provide comfortable, safe living quarters for the resident crew members.

1.2.3.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required for operation and maintenance of the satellite system. Included are satellite monitor and control stations and any centralized repair facilities not included under maintenance (WBS Numbers 1.1.1.6, 1.1.2.6, and 1.1.6.5).

1.2.3.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities.

1.2.3.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the O&M support facility. It includes both the direct and support personnel and the expendable maintenance supplies required in GEO for satellite operations and maintenance.

1.3 TRANSPORTATION

This element includes all space transportation required to support the satellite system assembly and operation; and the ground support facilities to provide a launch, recovery, propellant, logistics, and operational capability. Included are the launch to LEO and the orbit-to-orbit transfer of all hardware, materials, and personnel required during the construction and lifetime operation of the satellite system.

1.3.1 HEAVY-LIFT LAUNCH VEHICLE (HLLV)

This element includes the HLLV vehicles and operations required to support the satellite system assembly and operation. Included is the launch to LEO of all space construction and support equipment, satellite system hardware, OTV's, propellants, and other consumables required throughout the satellite lifetime.

1.3.1.1 HLLV VEHICLE

This element includes the vehicle fleet procurement required to support the SPS project.

1.3.1.2 HLLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.2 CARGO ORBITAL TRANSFER VEHICLE (COTV)

This element includes the COTV vehicles and operations required to support the satellite system assembly and operation. Included is the LEO-to-GEO transfer of space construction and support equipment, satellite system hardware, spares, and propellants required throughout the satellite lifetime.

1.3.2.1 COTV VEHICLES

This element includes the vehicle fleet procurement required to support the SPS project.

1.3.2.2 COTV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.3 PERSONNEL LAUNCH VEHICLE (PLV)

This element includes the PLV and cargo vehicles of the growth Shuttle and operations required to support the satellite system assembly and operation. Included is the launch to LEO and return of all personnel and priority cargo required throughout the satellite construction period and operational lifetime.

1.3.3.1 PLV VEHICLES

This element includes the vehicle fleet procurement required to support the SPS project. Included are the vehicles for personnel transfer from earth to LEO and for cargo transfer as needed to support elements of the precursor phase of program development.

1.3.3.2 PLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.4 PERSONNEL ORBITAL TRANSFER VEHICLE (POTV)

This element includes the POTV vehicles and operations required to support the satellite system assembly and operation. Included is the LEO to GEO and return transfer of all personnel and priority cargo required throughout the satellite construction and operational periods.

1.3.4.1 POTV VEHICLES

This element includes the vehicle fleet procurement required to support the SPS project.

1.3.4.2 POTV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.5 PERSONNEL MODULE (PM)

This element includes the PM units and operations required to support the satellite system assembly and operation. Included is the LEO to GEO and return transfer of all personnel and critical hardware items required throughout the satellite construction and operational periods. The PM provides a crew habitat during the orbit-to-orbit transfers of personnel.

1.3.5.1 PM VEHICLES

This element includes the PM unit procurement required to support the SPS project.

1.3.5.2 PM OPERATIONS

This element includes the necessary operations (user charge per flight including payload integration) required to support the SPS project.

1.3.6 INTRA-ORBITAL TRANSFER VEHICLE (IOTV)

This element includes the IOTV vehicles and operations required to support the satellite system assembly and operation. Included is the intra-orbit transfer of cargo between the HLLV, COTV, construction facility, logistics support facility, and operational satellites.

1.3.6.1 IOTV VEHICLES

This element includes the necessary vehicle fleet procurement required to support the SPS project.

1.3.6.2 IOTV OPERATIONS

This element includes the necessary vehicle operations (recurring refurbishment and propellant costs) required to support the SPS project.

1.3.7 GROUND SUPPORT FACILITIES

This element includes all land, buildings, roads, shops, etc., required to support the cargo handling, launching, recovering, refurbishment, and operations of the space transportation system.

1.3.7.1 LAUNCH FACILITIES

This element includes the design and construction of the actual launch facility and its associated equipment. Included are land, buildings, and equipment required to support the various crews. It also includes the required control centers and administrative facilities.

1.3.7.2 RECOVERY FACILITIES

This element covers the design, construction, and equipping of the actual recovery facilities.

1.3.7.3 FUEL FACILITIES

This element includes fuel production facilities, storage and handling facilities, transportation, and delivery and safety facilities for both the fuel and the oxidizer. Also included are the facilities for fuels used in the various orbital transfer facilities.

1.3.7.4 LOGISTICS SUPPORT

This element includes the land, buildings, and handling equipment for the receiving, inspection, and storage and packaging of all payloads to be launched except for fuels and oxidizers.

1.3.7.5 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground support facilities. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground support facilities operation and maintenance.

1.4 GROUND RECEIVING STATION

This element includes the land, facilities, and equipment that comprise the ground subsystems utilized to receive the radiated microwave power beam and to provide the power at the required voltage and type of current for entry into the national power grid. Also included are the equipment and facilities necessary to provide operational control over the satellite.

1.4.1 SITE AND FACILITIES

This element encompasses the site and facilities for the ground receiving station system which includes the rectenna, grid interface, and satellite control subsystems. Included are the land, site preparation, roads, fences, utilities, lightning protection, buildings, and maintenance equipment required to house and support the other ground station subsystems.

1.4.2 RECTENNA SUPPORT STRUCTURE

This element includes the hardware, materials (steel and concrete), and assembly operations necessary to erect the physical support for the rectenna array elements of WBS No. 1.4.3.

1.4.3 POWER COLLECTION

This element includes the antenna array elements associated with the actual reception and rectification of the microwave radiation. These elements are in series and parallel as required to deliver the required output voltage and

current. Also included are those components that accept the dc power from the array elements and route, control, convert, and switch this power for delivery to power conversion stations of the grid interface.

1.4.4 CONTROL

This element includes the hardware that will be used to monitor and control the satellite from the ground. Included are telemetry, tracking, communications, monitoring of microwave beam characteristics, computing phase corrections, and providing frequency standard signals for the satellite. Functional requirements provide for signal conditioning, formatting, software, computations, and signal routing.

1.4.5 GRID INTERFACE

This element includes the power conversion equipment that receives the electrical power from the power collection subsystem and conditions/converts it to a high voltage dc or ac power acceptable for input into the national power grid. Also included are those components necessary to route, control, and switch this power into the national power grid.

1.4.6 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground receiving station. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground station operation and maintenance.

1.5 MANAGEMENT AND INTEGRATION

This element includes all efforts and material required for management and integration functions at the systems level and program level. It encompasses the following functions:

a) Program Administration
b) Program Planning and Control
c) Contracts Administration
d) Engineering Management
e) Manufacturing Management
(f) Support Management
(g) Quality Assurance Management
(h) Configuration Management
(i) Data Management
(j) Systems Engineering and Integration

This element sums all of the direct effort required to provide management control, including planning, organizing, directing, and coordinating the project to ensure that overall project objectives are accomplished. These efforts overlay the functional work areas (e.g., engineering, manufacturing, etc.) and assure that they are properly integrated. This element also includes the efforts required in the coordination, gathering, and dissemination of management information. Also included are the engineering efforts related to the establishment and maintenance of a technical baseline for a system by generation of system configuration parameters, criteria, and requirements. It includes requirements analysis and integration, system definition, system test definition, interfaces, safety, reliability and maintainability. It also includes those efforts required to monitor the system development and operations to ensure that the design conforms to the baseline specifications.

APPENDIX B

SATELLITE POWER SYSTEM
COST ESTIMATING RELATIONSHIPS (CERs)

SOLAR PHOTOVOLTAIC GaAlAs
CONCENTRATION RATIO (CR) - 2
THREE-TROUGH COPLANAR
END-MOUNTED ANTENNA
CONFIGURATION

APPENDIX B
SATELLITE POWER SYSTEM
COST ESTIMATING RELATIONSHIPS (CERs)

B.0 INTRODUCTION

This appendix contains the cost analyses and a description of cost elements that comprise the SPS program. Each item is presented in accordance with the work breakdown structure of Appendix A and is responsive to the Rockwell reference configuration defined under Exhibit C of NAS8-32475 -- a 3-trough planar array with an end mounted tension web antenna (Figure B-1).

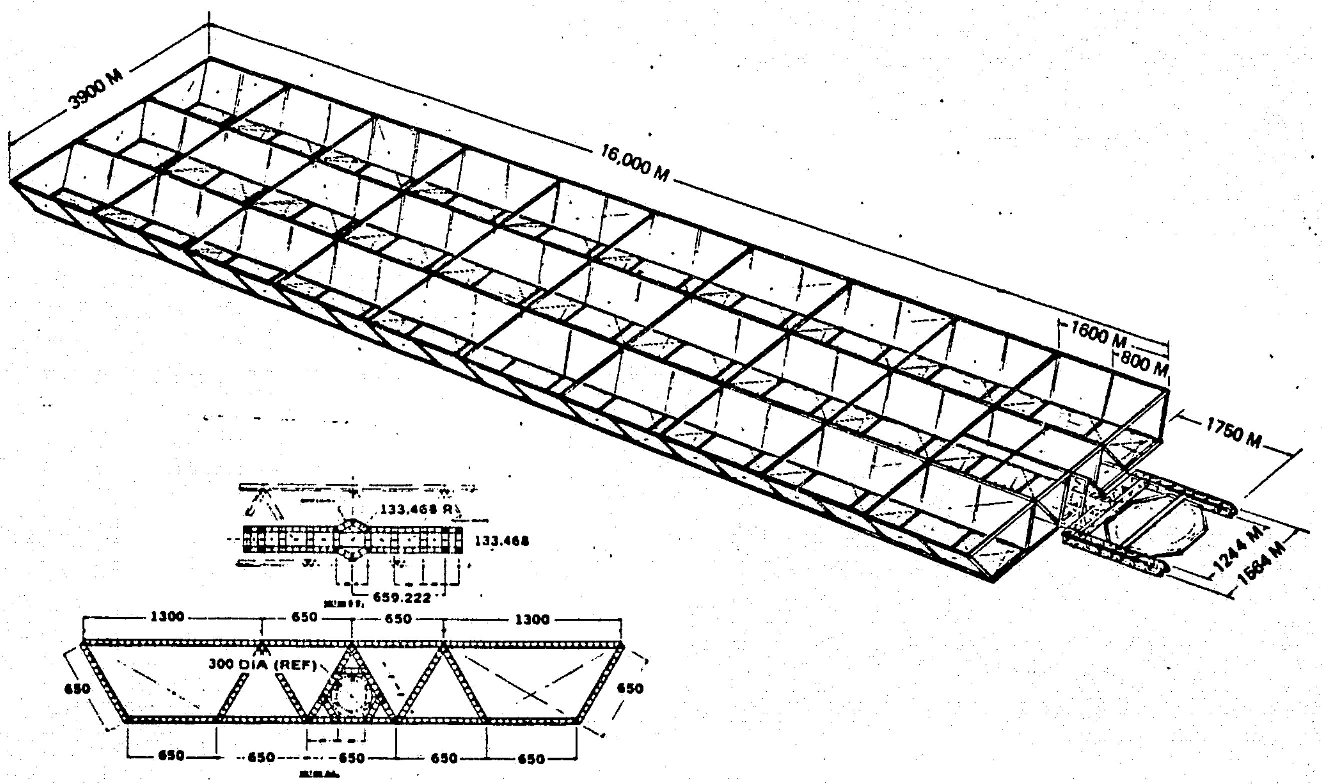

Figure B-1. SPS Reference Configuration

Subsequent sections of this appendix describe the definitions and ground rules used during the cost analysis; the methodology followed in developing estimates and the computer program; plus a detailed discussion of each subsystem, assembly, or component used in the analysis. These descriptions include design input parameters, cost estimates, scaling exponents/factors, and supporting computer program cost model equations for each of the WBS items.

B.1 COSTING GROUND RULES AND GUIDELINES

The following major ground rules and assumptions were used in the performance of this study:

1. The SPS WBS of Appendix A was used as the structure of program hardware, activities and accounts.

2. Key dates of program planning:

1980 - 1985	Ground Based Exploratory Research Activities
1981 - 1987	Key Technology Program Activities
1990	Decision Point for SPS Commercialization (Phase C/D)
2000	IOC of First SPS

3. Costs are reported at WBS level in terms of:

   (a) Development cost and TFU (theoretical first unit).

   (b) Initial capital investment average cost per satellite (Satellites TFU and No. 2 through No. 60).

   (c) Replacement capital investment (RCI) cost and operations and maintenance (O&M) cost per satellite per year.

4. Cost estimates are projected in 1977 dollars and maximum use was made of past SPS studies and other associated data as appropriate.

5. SPS build rate will be two nominal 5 GW SPS systems per year for 30 years to provide a total capacity of 300 GWs by 2030.

6. Overall SPS lifetime will be 30 years with minimum maintenance and no salvage value or disposition costs.

7. Complete construction and assembly will occur at GEO synchronous orbit.

8. Calculations based on 0% launch losses.

9. Program management and SE&I (management and integration) are costed at 5% of all other level 2 costs.

10. 25% mass contingency is costed as a 15% cost contingency on items 1.1, 1.2, and 1.3 of the SPS WBS.

B.2 COSTING METHODOLOGY

The approach followed in developing cost estimates for the SPS Program was based on the maximum use of contract and company sponsored work. The basic Rockwell - NASA/MSFC computer cost model was expanded considerably to incorporate the requirements of a revised WBS structure (Appendix A). The data base

of existing and proved CERs was expanded by grass roots analysis and specific engineering estimates on the flight vehicles and ground receiving station to provide cost projections based on industrial/consultant experience and on similar contract effort such as those of the Rockwell Space Shuttle and Space Station programs. Costing of some WBS elements utilized previously developed data with slight modification to incorporate reference systems specifications.

There are a series of equations that were used to deal with the four basic types of cost accounts and phases of the program -- DDT&E, initial capital investment, replacement capital investment, and operations and maintenance.

The DDT&E equation (CD) estimates the cost of the design, development, and test/evaluation of WBS line items for the satellite, space construction and support, transportation, and ground receiving station, plus management and integration support. Management and integration are costed as a separate line item at 5% of all other level two costs of the WBS. Because of the gross nature of the level of information/definition on systems test and GSE (ground support equipment), the cost of system test hardware, and system test operations, has been assumed to be one-half of the satellite system first-unit costs. A 10% factor of satellite DDT&E is used for GSE.

The appropriate inputs for the DDT&E CERs are the applicable total system mass, area, or power. A development factor is provided in the equation (DF) to adjust the cost to reflect only that portion of the total system mass, area or power considered necessary for development of the complete system where it is not required to develop the total mass, area or power. The CD cost equation also allows for the application of a complexity factor (CF) to adjust the cost results when it is determined that the item being estimated is either more or less complex than the CER base data.

The initial capital investment (ICI) cost equations estimate the initial capital investment cost of hardware items as a function of their mass, area or power. The ICI cost equation is expressed in four different forms -- CLRM, CTFU, CTB, and CIPS. The CLRM (cost of lowest repeating module) equation requires that the input correspond to the mass, area or power of the lowest repeating module (M). This is necessary because of the physical scale of the SPS and the production quantities required for many of the hardware elements. It is not reasonable to estimate the SPS initial capital investment cost as a historical function of the entire SPS mass, area or power. Instead, it is desirable to cost the number of repeating modules required per satellite to establish the satellite theoretical first-unit cost (TFU), and to input the satellite TFU cost into a progress (learning) function for the quantity of satellites required to calculate the average unit cost (CTB - cost to build). This calculation involves two steps in the cost equations. The first step (CLRM) is simply the portion of the equation which estimates the theoretical first repeating module cost as discussed above. The second step (CTFU) has the progress function incorporated into the equation for the quantity of repeat modules required for the first satellite. It automatically takes into account the progress over production quantities required when calculating the cost to build an average unit over the total option quantity. This CTB calculation is then the basis of CIPS, where the number of units to construct a satellite option are divided by the option quantity and then multiplied by the

CTB. In some ICI cost equations, such as those of SPS transportation, the space vehicle has a service life that is greater than that needed to construct a single satellite. The CIPS equation provides the cost model with a needed program flexibility.

At the current level of SPS definition, it was difficult to decide just what is a repeating module. It is often impossible to know with any certainty just what portion of the total mass is appropriate to run through the equation as a module. It is just as difficult to identify how many distinct types or designs of modules will be required for any subsystem or assembly. In such cases, the study simply assumed a module mass (or area or power) based on engineering best judgment.

Replacement capital investment (CRCI) CERs simply provide for the multiplication of the annual spares fraction (R) of each system by that system's cost to build in order to arrive at an RCI cost per satellite per year.

Operations and maintenance costs (CO&M) are estimated in terms of O&M cost per satellite per year. O&M costs include those expenditures incurred in day-to-day operations beginning with SPS initial operating capability (IOC) and continuing over the life of each satellite. They consist of wages of operations and maintenance personnel, minor repairs and adjustments to systems to maintain an ordinarily efficient operating condition, expendables and consumables, launch costs for delivery and transfer of on-orbit personnel and cargo resupply of expendables and consumables, etc.

The cost methodology seeks to account for five separate effects which influence SPS cost. These are scaling, specification requirements, complexity, the degree of automation, and production progress. Scaling refers to the relationship in cost between items varying in size, but similar in type. Economies of scale usually assure that such a relationship will not be strictly linear, but rather as size increases, cost per unit of size will decrease. The slope of this relationship is reflected by the equation exponent which results from the regression analysis of the data used to develop the cost estimating relationship.

Specification requirements have been accounted for by normalizing the CER data base to manned spacecraft specification levels using factors from the RCA Price Model.[1] From that model, an average cost factor to adjust MILSPEC to manned spacecraft is around 1.75 for DDT&E and 1.6 for production cost. Under the assumption that some relaxation of Apollo-type specifications can be made for the SPS, a factor of 1.5 was assumed for both DDT&E and production cost. Furthermore, it was assumed that a factor of 3.0 would adjust commercial specifications to SPS requirements. Therefore, military or commercial cost data used in the CERs were adjusted upward by factors of 1.5 and 3.0, respectively.

The cost equations allow a complexity factor input to adjust the cost result when it is determined that the item being estimated is either more or less complex than the listed CER data base.

[1] *Equipment Specification Cost Effect Study*, Phase II Final Report, Nov. 30, 1976, by RCA Government Systems Division

The degree of automation is accounted for in certain cost equations through an adjustment to the CER coefficient by the tooling factors given in Table B-1. The effect of tooling is dependent upon the annual production rate. Higher production rates allow harder tooling and, thus, effect cost reductions. The tooling factors are used only on those CERs which are based on historical aerospace programs with limited annual production rates. Tooling factors are not used on those CERs which are based on data already reflecting automated production techniques (e.g., the commercial electronics data for the microwave antenna CER).

Table B-1. SPS Tooling Factors

AVERAGE ANNUAL PRODUCTION RATE (AAPR)	TOOLING FACTOR (TF)	PROGRESS FRACTION (ø)
1-2	1-0	0.80
3-5	0.9	0.80
6-9	0.8	0.80
10-19	0.7	0.85
20-39	0.6	0.85
40-69	0.5	0.85
70-109	0.4	0.85
110-159	0.3	0.90
160-219	0.2	0.90
220-999	$(AAPR)^{-0.35}$	0.90
1000-9999	$(AAPR)^{-0.35}$	0.95
10,000	$(AAPR)^{-0.35}$	0.98

The decreasing cost effects of progress due to production process improvements or direct labor learning are accounted for through standard progress functions. Many SPS components will be mass produced in a capital intensive manner and will experience little labor learning. Other SPS hardware items, however, will be produced at very low annual rates, much in the labor-intensive manner of historical spacecraft programs, and therefore would experience learning. (Technically distinguishable from learning, but still predictable with the same form of exponential function, are the effects of production process improvement. In this model, when progress functions are used, they are meant to account for both of these effects.) A constant relationship has been assumed between the progress fraction and the annual production rate as given in Table B-1.

As required by the costing ground rules and assumptions, all CERs are in terms of 1977 dollars. The study did assume 1990 technology and 1990 supply/demand conditions which, in some cases, resulted in differential (non-general) price inflation or deflation between 1977 and 1990 being included in the CERs. Specifically, it was assumed that composite raw material prices and some electronic component prices will decrease relative to general prices while aluminum coil stock prices will increase relative to general prices. Such effects are allowed for by the CERs, but only to the extent that the expected price changes differ from expected general price changes. The CERs affected are the antenna structure CER, the power source structure CER, and the microwave antenna CER.

Definitions of SPS cost model terms and equation abbreviations are presented in Table B-2.

Table B-2. Definitions of SPS Cost Model Elements

C	= COST IN MILLIONS OF 1977 DOLLARS
CD	= DDT&E COST
CDCER	= DDT&E COST ESTIMATING RELATIONSHIP (CER)
CDEXP	= DDT&E SCALING EXPONENT
CER	= COST ESTIMATING RELATIONSHIP
CF	= COMPLEXITY FACTOR
CICER	= INITIAL CAPITAL INVESTMENT COST ESTIMATING RELATIONSHIP (CER)
CIEXP	= INITIAL CAPITAL INVESTMENT COST SCALING EXPONENT
CTB	= COST TO BUILD AN ITEM
CIPS	= INVESTMENT PER SATELLITE COST
CLRM	= LOWEST REPEATING MODULE COST
CO&M	= OPERATIONS AND MAINTENANCE COST PER SATELLITE PER YEAR
CRCI	= REPLACEMENT CAPITAL INVESTMENT COST PER SATELLITE PER YEAR
CTFU	= THEORETICAL FIRST UNIT COST
DDT&E	= DESIGN, DEVELOPMENT, TEST AND EVALUATION
DF	= DEVELOPMENT FRACTION
E	= 1.0 + LOG (PHI) ÷ LOG (2.0)
ICI	= INITIAL CAPITAL INVESTMENT
INV. PER SAT.	= AVERAGE UNIT INVESTMENT COST (2 THRU N)
M	= MASS, POWER, AREA OF LOWEST REPEATING MODULE
#RM	= NUMBER OF REPEATING MODULES
OPS	= OPERATIONS
O&M	= OPERATIONS AND MAINTENANCE COST PER SATELLITE PER YEAR
PHI	= PROGRESS FRACTION
R	= ANNUAL SPARES FRACTION
RCI	= REPLACEMENT CAPITAL INVESTMENT COST PER SATELLITE PER YEAR
T	= TOTAL (MASS, POWER, AREA) PER SATELLITE
TF	= TOOLING FACTOR
TFU	= THEORETICAL FIRST UNIT
Z1	= TFU REQUIREMENT
Z2	= SPS OPTION QUANTITY
Z3	= TOTAL SPS REQUIREMENT PER OPTION
Z4	= ITEMS NEEDED TO CONSTRUCT SATELLITE OPTION
Z5	= ITEMS NEEDED FOR O&M OF THE SATELLITE OPTION

B.3 SPS PROGRAM COST BREAKDOWNS

An overall cost relationship for the SPS program is shown in Figure B-2. Principal areas of SPS costing are represented to indicate the emphasis on expenditures as the program moves from one phase to the next.

Subsequent tables summarize the cost data used in developing Figure B-2. They reflect SPS-related development cost DDT&E (CD) data through the first 5-GW satellite (TFU). **Table B-3 includes space construction/support, transportation**

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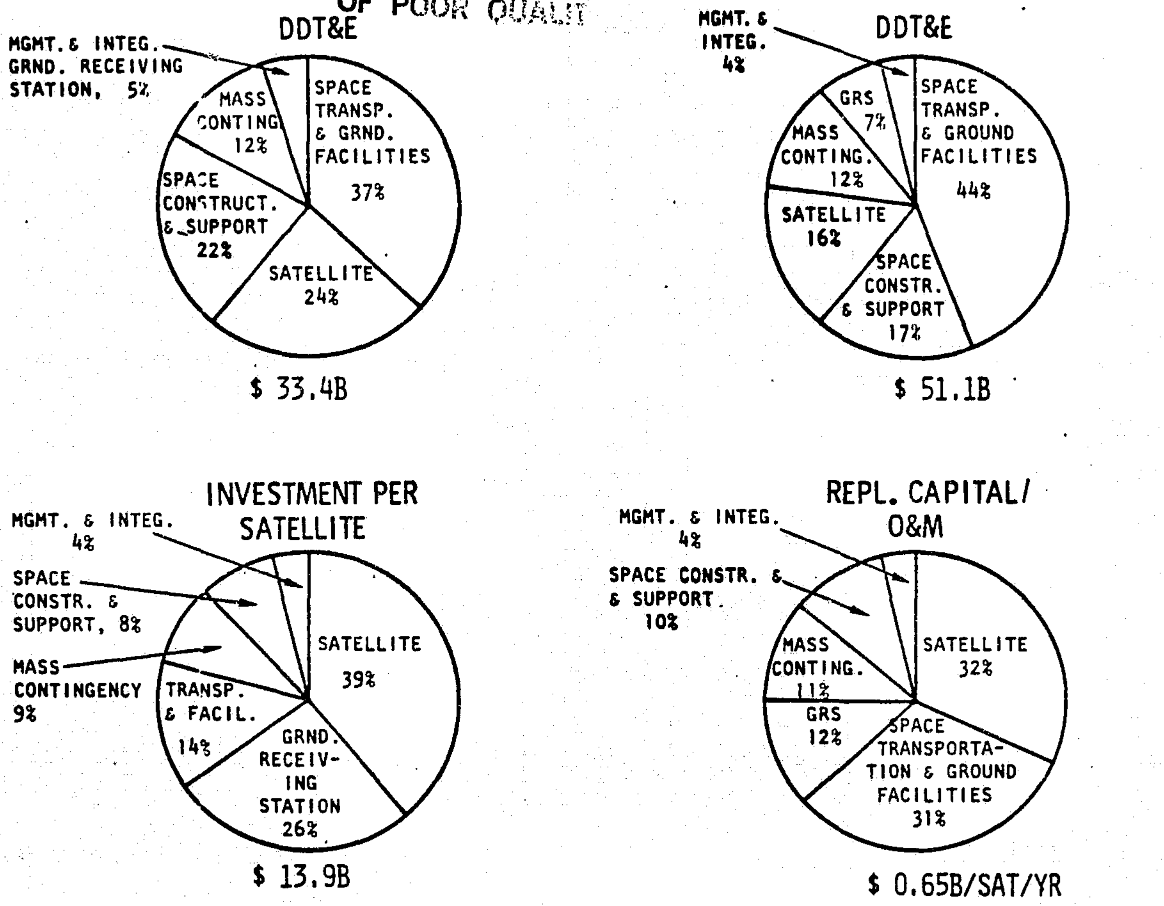

Figure B-2. SPS Cost Relationships

vehicles/operations, and the ground receiving station needed to establish SPS operational capability. This means that the TFU cost includes elements with a lifetime capability of building more than one SPS. Table B-4 summarizes the investment cost per satellite (CIPS) and the replacement capital investment cost (CRCI) plus operations and maintenance (CO&M) per satellite per year.

Table B-3. SPS Program Development Cost

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	TFU	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	33401.762	51103.242	84505.000
1.1	SATELLITE SYSTEM	7933.570	7950.922	15884.492
1.2	SPACE CONSTRUCTION & SUPPORT	7331.180	8602.523	15933.703
1.3	TRANSPORTATION	12468.816	22866.199	35335.016
1.4	GROUND RECEIVING STATION	115.699	3618.727	3734.427
1.5	MANAGEMENT AND INTEGRATION	1392.463	2151.918	3544.382
1.6	MASS CONTINGENCY	4160.031	5912.945	10072.977

Table B-4. SPS Program Average Cost

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	13877.666	451.531	193.713	645.244	14522.910
1.1	SATELLITE SYSTEM	5325.422	205.265	0.705	205.970	5531.391
1.2	SPACE CONSTRUCTION & SUPPORT	1148.332	51.428	11.274	62.701	1211.033
1.3	TRANSPORTATION	1949.004	119.343	80.869	200.212	2149.216
1.4	GROUND RECEIVING STATION	3590.822	0.275	78.377	78.652	3669.474
1.5	MANAGEMENT AND INTEGRATION	600.679	18.815	8.561	27.377	628.055
1.6	MASS CONTINGENCY	1263.413	56.405	13.927	70.332	1333.745

B.3.1 DEVELOPMENT COST (DDT&E) AND THEORETICAL FIRST UNIT (TFU)

The total program DDT&E and TFU cost for a first full-up nominal 5-GW SPS system is $84.5 billion. The DDT&E of $33.4 billion and the $51.1 billion for the TFU are detailed by SPS WBS line item in a subsequent table. Detailed DDT&E cost breakdowns show that over 60% of the DDT&E cost is identifiable to transportation and support systems, and the satellite system.

In view of the physical size of the satellite and supportive subsystems and the large quantities required for certain parts and components, it was not considered reasonable to estimate the DDT&E costs as a function of the total mass, area, or power per subsystem—which is generally the method; instead, it was considered desirable to determine the DDT&E costs by application of a development factor (DF). In general, the DF was applied on the basis of a particular system/component in conjunction with the engineering staff and as related to the program development scenario and the usage/availability of the system when needed. For example, the 335-MW EOTV precursor test article is required early in the program for MW verification. The SCB will build this unit first and the DDT&E effort on the many components must be satisfied before items can be made available. Typical items include the structure, concentrators, solar cells, power distribution, and supporting systems that are design verifications of the full-up SPS satellite. As a result of this approach, a 1.0 DF was used on components of the EOTV test article; whereas on other usages of these systems, such as on the EOTV's or similar systems of the satellite itself, a reduced factor was applied in recognition of the earlier completed DDT&E effort. This rationale was also followed in other areas of the SPS program cost analysis.

DDT&E and TFU cost breakdowns are shown in Table B-5. The TFU listing reflects a somewhat different makeup of costs when compared to the DDT&E costs. TFU estimates of $51.1 billion include the full dollar assessment for an initial satellite and ground receiving station, include space transportation fleets; the LEO, SCB, and support assembly equipment; and the facilities needed to establish a 5-GW SPS operational capability. This means that the TFU cost includes elements with a lifetime capability of servicing/building more than one SPS system. In this regard, analysis will show that transportation and space construction and support equipment represent the largest portion of total TFU costs. However, these systems will be used to construct remaining satellites.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	DEVELOPMENT TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	33401.762	51103.242	84505.000
1.1	SATELLITE SYSTEM	7933.570	7950.922	15884.492
1.1.1	ENERGY CONVERSION	118.065	2007.983	2126.048
1.1.1.1	STRUCTURE	71.066	104.608	175.674
1.1.1.1.1	PRIMARY STRUCTURE	47.821	35.100	82.921
1.1.1.1.2	SECONDARY STRUCTURE	23.245	69.508	92.753
1.1.1.2	CONCENTRATORS	0.0	75.637	75.637
1.1.1.3	SOLAR BLANKETS	0.0	1651.832	1651.832
1.1.1.4	POWER DIST. & CONDITIONG	46.999	126.986	173.984
1.1.1.4.1	SWITCH GEAR & CONVERTERS	3.582	89.123	92.704
1.1.1.4.2	CONDUCTORS & INSULATION	6.234	9.468	15.702
1.1.1.4.3	SLIP RINGS	7.392	27.626	35.018
1.1.1.4.4	BATTERIES	5.001	0.338	5.339
1.1.1.4.5	BATTERY PD&C	24.790	0.430	25.220
1.1.1.5	THERMAL CONTROL	0.0	0.0	0.0
1.1.1.6	MAINTENANCE	0.0	48.921	48.921
1.1.1.6.1	MAINTENANCE - FREE FLYERS	0.0	29.299	29.299
1.1.1.6.2	MANNED MANIPULATOR	0.0	19.203	19.203
1.1.1.6.3	TRACKS & ACCESS WAYS	0.0	0.420	0.420
1.1.2	POWER TRANSMISSION	883.144	3816.522	4699.664
1.1.2.1	STRUCTURE	26.007	49.349	75.356
1.1.2.1.1	PRIMARY STRUCTURE	7.301	3.350	10.651
1.1.2.1.2	SECONDARY STRUCTURE	18.705	45.999	64.704
1.1.2.2	TRANSMITTER SUBARRAYS - KLYSTRONS	102.576	2702.309	2804.885
1.1.2.2.1	KLYSTRON DDT&E	102.576	0.0	102.576
1.1.2.2.2	KLYSTRON ICI, R, O&M	0.0	2702.309	2702.309
1.1.2.3	POWER DIST. & CONDITIONING	12.393	769.800	782.193
1.1.2.3.1	SWITCH GEAR & CONVERTERS	7.132	752.336	759.468
1.1.2.3.2	CONDUCTORS & INSULATION	5.262	5.348	10.610
1.1.2.3.3	BATTERIES	0.0	12.115	12.115
1.1.2.4	THERMAL CONTROL - INSULATION	29.136	208.062	237.198
1.1.2.5	CONTROL - PHASE REFERENCE	0.373	20.050	20.423
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	0.100	0.100	0.200
1.1.2.5.2	DIST. SYSTEM, COAXIAL CABLE	0.203	12.180	12.383
1.1.2.5.3	DIST. SYSTEM, DEVICES	0.070	7.770	7.840

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1.1.2.6	MAINTENANCE	712.660	66.953	779.613
1.1.2.6.1	MAINTENANCE - FREE FLYERS	0.0	36.368	36.368
1.1.2.6.2	GANTRY CRANE	91.060	0.220	91.280
1.1.2.6.3	ON-CRANE CONTROL CENTER	621.600	30.305	651.905
1.1.2.6.4	TRACKS & ACCESS WAYS	0.0	0.060	0.060
1.1.3	INFORMATION MGMT. & CONTROL	72.565	196.897	269.462
1.1.3.1	MASTER CONTROL COMPUTER	16.127	7.845	23.972
1.1.3.2	DISPLAYS & CONTROLS	10.745	1.211	11.956
1.1.3.3	SUPERVISORY COMPUTER	2.753	2.325	5.078
1.1.3.4	REMOTE COMPUTER	2.643	5.696	8.339
1.1.3.5	BUS CONTROL UNIT	0.415	6.940	7.354
1.1.3.6	MICROPROCESSORS	0.431	6.881	7.312
1.1.3.7	REMOTE ACQUISITION & CONTROL	0.414	7.450	7.864
1.1.3.8	SUBMULTIPLEXORS	0.266	66.119	66.385
1.1.3.9	INSTRUMENTATION	28.000	74.192	102.192
1.1.3.10	OPTICAL FIBER	0.807	0.634	1.442
1.1.3.11	CABLES/HARNESS	9.963	17.604	27.567
1.1.4	ATTITUDE CONTROL & STATIONKEEPING	8.183	72.488	80.671
1.1.4.1	ACSS HARDWARE	8.183	72.488	80.671
1.1.4.2	ACSS PROPELLANT	0.0	0.0	0.0
1.1.5	COMMUNICATIONS	0.0	0.0	0.0
1.1.5.1	SATELLITE TO GROUND	0.0	0.0	0.0
1.1.5.2	SATELLITE TO RESUPPLY VEHICLES	0.0	0.0	0.0
1.1.5.3	SATELLITE INTERCOM	0.0	0.0	0.0
1.1.6	INTERFACE	56.309	118.560	174.869
1.1.6.1	STRUCTURE	35.115	76.827	111.942
1.1.6.1.1	PRIMARY STRUCTURE	11.638	6.000	17.638
1.1.6.1.2	SECONDARY STRUCTURE	23.476	70.827	94.303
1.1.6.2	MECHANISMS - INTERFACE	15.225	7.878	23.103
1.1.6.3	POWER DISTRIBUTION	5.969	7.003	12.972
1.1.6.3.1	CONDUCTOR & INSULATION	5.178	5.068	10.246
1.1.6.3.2	SLIP RING BRUSHES	0.791	1.935	2.726
1.1.6.4	THERMAL CONTROL	0.0	0.0	0.0
1.1.6.5	MAINTENANCE	0.0	26.852	26.852
1.1.6.5.1	MAINTENANCE - FREE FLYERS	0.0	7.530	7.530

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1.1.6.5.2	MANNED MANIPULATOR	0.0	19.203	19.203
1.1.6.5.3	TRACKS & ACCESS WAYS	0.0	0.120	0.120
1.1.7	SYSTEMS TEST	5325.422	0.0	5325.422
1.1.7.1	SYSTEM GROUND TEST HARDWARE	2662.711	0.0	2662.711
1.1.7.2	SYSTEM GROUND TEST OPERATIONS	2662.711	0.0	2662.711
1.1.8	GROUND SUPPORT EQUIPMENT	721.234	0.0	721.234
1.1.9	COTV - PRECURSOR	748.653	1738.474	2487.127
1.1.9.1	COTV PRECURSOR VEHICLE	748.653	1737.844	2486.497
1.1.9.1.1	PRIMARY STRUCTURE - E.C.	89.863	1.544	91.408
1.1.9.1.2	SECONDARY STRUCTURE - E.C.	21.178	533.576	554.754
1.1.9.1.3	CONCENTRATOR - E.C.	7.869	2.817	10.686
1.1.9.1.4	SOLAR BLANKET -E.C.	47.041	60.300	107.341
1.1.9.1.5	SWITCHGEAR & CONVERTERS -E.C.	3.497	1.725	5.222
1.1.9.1.6	CONDUCTORS & INSULATION - E.C.	7.048	1.431	8.478
1.1.9.1.7	ACS HARDWARE - E.C.	12.190	620.634	632.823
1.1.9.1.8	SLIPRINGS - PRECURSOR	54.565	30.980	85.546
1.1.9.1.9	PRIMARY STRUCTURE - INTERFACE	152.844	6.000	158.844
1.1.9.1.10	SECONDARY STRUCTURE - INTERFACE	15.155	4.047	19.202
1.1.9.1.11	MECHANISMS - INTERFACE	78.868	221.647	300.514
1.1.9.1.12	CONDUCTORS & INSULATION	3.993	0.211	4.204
1.1.9.1.13	SLIPRING BRUSHES - PRECURSOR	2.529	2.268	4.797
1.1.9.1.14	PRIMARY STRUCTURE - POWER TRANS	20.936	0.250	21.186
1.1.9.1.15	SECONDARY STRUCTURE - POWER TRANS	17.041	2.546	19.587
1.1.9.1.16	TRANSMITTER SUBARRAYS - KLYSTRONS ICI	0.0	141.497	141.497
1.1.9.1.17	SWITCHGEAR & CONVERTERS - P.T. PRECURSOR	6.756	47.520	54.276
1.1.9.1.18	CONDUCTORS & INSULATION - P.T. PRECURSOR	4.147	0.240	4.387
1.1.9.1.19	BATTERIES - P.T. PRECURSOR	27.106	11.501	38.607
1.1.9.1.20	THERMAL CONTROL - INSULATION - PRECURSOR	26.539	45.996	72.535
1.1.9.1.21	REFERENCE FREQUENCY GENERATOR - PRECURSOR	0.500	0.100	0.600
1.1.9.1.22	DIST. SYSTEM, COAXIAL CABLE	0.258	0.517	0.775
1.1.9.1.23	DIST. SYSTEM DEVICES	0.022	0.500	0.522
1.1.9.1.24	TRANSMITTER SUBARRAYS - KLYSTRONS DDT&E	148.707	0.0	148.707
1.1.9.2	COTV PRECURSOR OPERATIONS	0.0	0.630	0.630
1.2	SPACE CONSTRUCTION & SUPPORT	7331.180	8602.523	15933.703
1.2.1	CONSTRUCTION FACILITIES	3653.249	6575.176	10228.422

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.2.1.1	WORK SUPPORT FACILITIES	3092.417	3956.069	7048.484
1.2.1.1.1	BEAM MACHINE	2.000	83.150	85.150
1.2.1.1.2	BEAM MACHINE CASSETTES	0.800	6.315	7.115
1.2.1.1.3	CABLE ATTACHMENT MACHINE	4.300	28.228	32.528
1.2.1.1.4	REMOTE MANIPULATOR	6.880	60.390	67.270
1.2.1.1.5	BLANKET DISPENSER MACHINE	4.000	26.154	30.154
1.2.1.1.6	SOLAR BLANKET CASSETTES	0.800	9.076	9.876
1.2.1.1.7	REFLECTOR DISPENSER MACHINE	6.000	4.651	10.651
1.2.1.1.8	REFLECTOR CASSETTES	1.000	2.721	3.721
1.2.1.1.9	CABLE/CATENARY DISPENSER MACHINES	2.200	22.786	24.986
1.2.1.1.10	ANTENNA PANEL INS. EQPT.	80.000	200.272	280.272
1.2.1.1.11	GANTRY/CRANES	13.600	85.034	98.634
1.2.1.1.12	CARGO STORAGE DEPOTS	12.000	7.559	19.559
1.2.1.1.13	FAB FIXTURE	2165.128	82.445	2247.573
1.2.1.1.14	AIRLOCK DOCKING MODULE (ADM)	0.0	242.302	242.302
1.2.1.1.15	BASE MGMT. MODULE (BMM)	0.0	1213.870	1213.870
1.2.1.1.16	POWER MODULE (PM)	0.0	1075.459	1075.459
1.2.1.1.17	PRESSURIZED STORAGE MODULE (PSM)	793.710	805.657	1599.367
1.2.1.2	CREW SUPPORT FACILITIES-SCB	560.832	2590.290	3151.122
1.2.1.2.1	AIRLOCK DOCKING MODULE-ADM	31.152	73.413	104.565
1.2.1.2.2	CREW HABITABILITY MODULE-CHM	0.0	1634.456	1634.456
1.2.1.2.3	CONSUMABLES LOGISTICS MODULE-CLM	0.0	604.675	604.675
1.2.1.2.4	SHIELDING	343.200	21.160	364.360
1.2.1.2.5	CREW SUPPORT MODULE-CSM	186.480	256.587	443.067
1.2.1.3	OPERATIONS	0.0	28.819	28.819
1.2.1.3.1	OPERATIONS, CONSTRUCTION CREW	0.0	19.781	19.781
1.2.1.3.2	ORBITAL OPERATIONS,CONST. PROV.	0.0	9.038	9.038
1.2.2	LOGISTICS SUPPORT FACILITIES-LEO	3677.934	917.151	4595.082
1.2.2.1	WORK SUPPORT FACILITIES	2814.992	586.187	3401.179
1.2.2.1.1	BASE MGMT. MODULE-BMM	2464.993	310.814	2775.806
1.2.2.1.2	POWER MODULE-PM	350.000	275.373	625.373
1.2.2.2	CREW SUPPORT FACILITIES	862.942	328.782	1191.724
1.2.2.2.1	CREW HABITABILITY MODULE-CHM	262.278	101.928	364.206
1.2.2.2.2	CONSUMABLES LOGISTICS MODULE	265.000	70.095	335.095
1.2.2.2.3	CREW SUPPORT MODULE/EVA	335.664	156.759	492.423

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TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.2.2.3	OPERATIONS	0.0	2.182	2.182
1.2.2.3.1	LEO OPERATIONS CREW	0.0	1.498	1.498
1.2.2.3.2	LEO CREW PROVISIONS	0.0	0.684	0.684
1.2.3	O&M SUPPORT FACILITIES - SATELLITE	0.0	1110.198	1110.198
1.2.3.1	WORK SUPPORT FACILITIES	0.0	763.578	763.578
1.2.3.1.1	AIRLOCK DOCKING MODULE-ADM	0.0	44.520	44.520
1.2.3.1.2	BASE MGMT MODULE-BMM	0.0	310.814	310.814
1.2.3.1.3	PRESSURIZED STORAGE MODULE-PSM	0.0	408.244	408.244
1.2.3.2	CREW SUPPORT FACILITIES	0.0	343.893	343.893
1.2.3.2.1	AIRLOCK DOCKING MODULE-ADM	0.0	15.111	15.111
1.2.3.2.2	CREW HABITABILITY MODULE-CHM	0.0	101.928	101.928
1.2.3.2.3	CONSUMABLES LOGISTICS MODULE-CLM	0.0	70.095	70.095
1.2.3.2.4	CREW SUPPORT MODULE/EVA	0.0	156.759	156.759
1.2.3.3	OPERATIONS	0.0	2.727	2.727
1.2.3.3.1	SATELLITE OPERATIONS CREW	0.0	1.872	1.872
1.2.3.3.2	SATELLITE CREW PROVISIONS	0.0	0.855	0.855
1.3	TRANSPORTATION	12468.816	22866.199	35335.016
1.3.1	SPS-HEAVY LIFT LAUNCH VEHICLE(HLLV)	8600.000	9530.492	18130.492
1.3.1.1	SPS-HLLV FLEET	8600.000	8950.176	17550.176
1.3.1.2	SPS-HLLV OPERATIONS	0.0	580.320	580.320
1.3.2	CARGO ORBITAL TRANSFER VEHICLE(COTV)	31.818	3625.720	3657.538
1.3.2.1	COTV VEHICLES	31.818	3621.310	3653.128
1.3.2.1.1	PRIMARY STRUCTURE	3.930	9.267	13.197
1.3.2.1.2	SECONDARY STRUCTURE	4.582	2478.750	2483.332
1.3.2.1.3	CONCENTRATOR	1.685	15.818	17.503
1.3.2.1.4	SOLAR BLANKET	7.664	338.117	345.781
1.3.2.1.5	SWITCHGEAR AND CONVERTERS	2.054	8.760	10.814
1.3.2.1.6	CONDUCTORS AND INSULATION	2.205	8.584	10.789
1.3.2.1.7	ACS HARDWARE	9.697	762.015	771.712
1.3.2.1.8	INFO. MGMT. AND CONTROL	0.0	0.0	0.0
1.3.2.2	COTV OPERATIONS	0.0	4.410	4.410
1.3.3	PERSONNEL LAUNCH VEHICLE(PLV)	1549.000	6251.230	7800.230
1.3.3.1	STS-PLV FLEET	1549.000	3908.082	5457.082
1.3.3.1.1	STS-PLV ORBITER	0.0	1682.531	1682.531
1.3.3.1.2	STS-PLV EXTERNAL TANK	0.0	606.205	606.205

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.3.3.1.3	STS-PLV LIQ. ROCKET BOOSTER	1304.000	873.985	2177.985
1.3.3.1.4	STS CARGO CARRIER AND EM	245.000	745.362	990.362
1.3.3.2	PLV & STS-HLLV OPERATIONS	0.0	2343.150	2343.150
1.3.3.2.1	PLV OPERATIONS	0.0	1214.400	1214.400
1.3.3.2.2	STS HLLV CARGO OPERATIONS	0.0	1128.750	1128.750
1.3.4	PERSONNEL ORBITAL TRANS VEHICLE	350.000	56.282	406.282
1.3.4.1	POTV-FLEET	350.000	54.764	404.764
1.3.4.2	POTV-OPERATIONS	0.0	1.518	1.518
1.3.5	PERSONNEL MODULE(PM)	118.000	201.910	319.910
1.3.5.1	PM FLEET	118.000	198.610	316.610
1.3.5.2	PM OPERATIONS	0.0	3.300	3.300
1.3.6	INTRAORBITAL TRANSFER VEHICLE(IOTV)	100.000	5.567	105.567
1.3.6.1	IOTV FLEET	100.000	5.476	105.476
1.3.6.2	IOTV OPERATIONS	0.0	0.091	0.091
1.3.7	GROUND SUPPORT FACILITIES	1720.000	3195.000	4915.000
1.3.7.1	LAUNCH FACILITIES	0.0	0.0	0.0
1.3.7.2	RECOVERY FACILITIES	0.0	0.0	0.0
1.3.7.3	FUEL FACILITIES	0.0	0.0	0.0
1.3.7.4	LOGISTICS SUPPORT	0.0	0.0	0.0
1.3.7.5	OPERATIONS	0.0	0.0	0.0
1.4	GROUND RECEIVING STATION	115.699	3618.727	3734.427
1.4.1	SITE AND FACILITIES	1.000	195.197	196.197
1.4.1.1	LAND AND PREPARATION	0.0	105.341	105.341
1.4.1.1.1	LAND	0.0	35.000	35.000
1.4.1.1.2	LAND PREPARATION	0.0	70.341	70.341
1.4.1.2	ROADS AND FENCES	0.0	74.180	74.180
1.4.1.2.1	RAILS AND ROADS	0.0	73.710	73.710
1.4.1.2.2	FENCING	0.0	0.470	0.470
1.4.1.3	UTILITIES	0.0	0.200	0.200
1.4.1.4	BUILDINGS	0.0	11.477	11.477
1.4.1.4.1	STORAGE,MAINTENANCE	0.0	1.300	1.300
1.4.1.4.2	CONV. STA. & MONITOR/CONTROL FAC.	0.0	10.177	10.177
1.4.1.5	MAINTENANCE EQPT.	0.0	4.000	4.000
1.4.1.6	LIGHTNING PROTECTION	0.0	0.0	0.0
1.4.1.7	SITE & FACILITIES DDT&E	1.000	0.0	1.000

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.4.2	RECTENNA SUPPORT STRUCTURE	2.000	1849.629	1851.629
1.4.2.1	STEEL PANEL FAB. & INSTALLATION	0.0	1696.508	1696.508
1.4.2.1.1	HAT SECTIONS	0.0	359.228	359.228
1.4.2.1.2	WIDE FLANGES	0.0	295.173	295.173
1.4.2.1.3	TUBE BRACES & HARDWARE	0.0	431.346	431.346
1.4.2.1.4	ASSEMBLY & INSTALLATION	0.0	610.762	610.762
1.4.2.2	TRENCHING & CONCRETE INSTALLATION	0.0	153.121	153.121
1.4.2.2.1	FOOTING CONCRETE & RE-BAR	0.0	70.821	70.821
1.4.2.2.2	MACHINGERY & EQUIPMENT	0.0	22.360	22.360
1.4.2.2.3	CONSTRUCTION OPERATIONS	0.0	59.940	59.940
1.4.2.3	SUPPORT STRUCTURE DDT&E	2.000	0.0	2.000
1.4.3	POWER COLLECTION	3.000	1353.211	1356.211
1.4.3.1	ANTENNA ARRAY ELEMENTS	0.0	1127.331	1127.331
1.4.3.2	POWER DISTRIBUTION SYSTEM	0.0	69.660	69.660
1.4.3.3	INSTALLATION & CHECKOUT	0.0	156.220	156.220
1.4.3.4	POWER COLLECTION-DDT&E	3.000	0.0	3.000
1.4.4	CONTROL	10.000	75.000	85.000
1.4.4.1	CONTROL CENTER EQUIPMENT	0.0	15.000	15.000
1.4.4.2	CONTROL ELECTRONICS	0.0	60.000	60.000
1.4.4.3	CONTROL DDT&E	10.000	0.0	10.000
1.4.5	GRID INTERFACE	99.699	145.690	245.389
1.4.5.1	ELECTRICAL EQUIPMENT	0.0	145.690	145.690
1.4.5.2	GRID INTERFACE-DDT&E	99.699	0.0	99.699
1.4.6	OPERATIONS	0.0	0.0	0.0
1.4.6.1	OPER. & MAINT. PERSONNEL	0.0	0.0	0.0
1.4.6.2	MAINT. MATERIAL	0.0	0.0	0.0
1.5	MANAGEMENT AND INTEGRATION	1392.463	2151.918	3544.382
1.6	MASS CONTINGENCY	4160.031	5912.945	10072.977

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B.3.2 INVESTMENT AND OPERATIONS

Detailed investment and RCI/O&M cost data are shown in Table B-6. Investment costs were developed at two levels:

(1) Initial capital investment (ICI), which is the cost of production, assembly, installation, transportation, and tests of each individual satellite produced, and the ground station system and associated effort necessary to bring the power satellite on line to a 5-GW operational capability.

(2) Replacement capital investment (RCI), which are those expenditures relating to capital asset replacement and major maintenance overhauls/spares that are expected to last for more than one year or result in an improvement to the operating system.

Costs for the transportation fleet needed to construct the satellites are included in the ICI; whereas, the fleet required for O&M of the satellite over the 30 years is included in the O&M cost. Replacement capital investment is included in the RCI column.

Investment per satellite is equivalent to the average unit cost of the total SPS requirement—TFU plus satellites and supporting program elements for the 60-SPS option. Total average ICI cost is projected at $13.9 billion. Annual SPS estimates are placed at $0.45 billion for RCI and $0.20 billion for O&M.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RC1	O&M	TOTAL OPS	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	13877.668	451.531	193.713	645.244	14522.910
1.1	SATELLITE SYSTEM	5325.422	205.265	0.705	205.970	5531.391
1.1.1	ENERGY CONVERSION	1851.622	4.500	0.010	4.510	1856.132
1.1.1.1	STRUCTURE	96.789	0.194	0.0	0.194	96.983
1.1.1.1.1	PRIMARY STRUCTURE	35.100	0.070	0.0	0.070	35.170
1.1.1.1.2	SECONDARY STRUCTURE	61.689	0.123	0.0	0.123	61.812
1.1.1.2	CONCENTRATORS	67.183	0.134	0.0	0.134	67.318
1.1.1.3	SOLAR BLANKETS	1556.692	3.113	0.0	3.113	1559.805
1.1.1.4	POWER DIST. & CONDITIIONG	91.948	0.169	0.010	0.179	92.127
1.1.1.4.1	SWITCH GEAR & CONVERTERS	66.093	0.0	0.0	0.0	66.093
1.1.1.4.2	CONDUCTORS & INSULATION	9.468	0.0	0.0	0.0	9.468
1.1.1.4.3	SLIP RINGS	15.825	0.158	0.0	0.158	15.983
1.1.1.4.4	BATTERIES	0.238	0.008	0.010	0.018	0.256
1.1.1.4.5	BATTERY PD&C	0.324	0.003	0.0	0.003	0.327
1.1.1.5	THERMAL CONTROL	0.0	0.0	0.0	0.0	0.0
1.1.1.6	MAINTENANCE	39.010	0.890	0.0	0.890	39.899
1.1.1.6.1	MAINTENANCE - FREE FLYERS	23.392	0.585	0.0	0.585	23.977
1.1.1.6.2	MANNED MANIPULATOR	15.198	0.304	0.0	0.304	15.502
1.1.1.6.3	TRACKS & ACCESS WAYS	0.420	0.001	0.0	0.001	0.421
1.1.2	POWER TRANSMISSION	3153.938	197.438	0.485	197.923	3351.861
1.1.2.1	STRUCTURE	44.175	0.088	0.0	0.088	44.263
1.1.2.1.1	PRIMARY STRUCTURE	3.350	0.007	0.0	0.007	3.357
1.1.2.1.2	SECONDARY STRUCTURE	40.825	0.082	0.0	0.082	40.906
1.1.2.2	TRANSMITTER SUBARRAYS - KLYSTRONS	2322.804	154.854	0.0	154.854	2477.658
1.1.2.2.1	KLYSTRON DDT&E	0.0	0.0	0.0	0.0	0.0
1.1.2.2.2	KLYSTRON ICI, R, O&M	2322.804	154.854	0.0	154.854	2477.658
1.1.2.3	POWER DIST. & CONDITIONING	526.406	34.454	0.475	34.929	561.334
1.1.2.3.1	SWITCH GEAR & CONVERTERS	512.556	34.171	0.0	34.171	546.726
1.1.2.3.2	CONDUCTORS & INSULATION	5.348	0.0	0.0	0.0	5.348
1.1.2.3.3	BATTERIES	8.502	0.283	0.475	0.758	9.261
1.1.2.4	THERMAL CONTROL - INSULATION	184.657	1.847	0.0	1.847	186.504
1.1.2.5	CONTROL - PHASE REFERENCE	20.050	0.262	0.010	0.272	20.322
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	0.100	0.003	0.010	0.013	0.113
1.1.2.5.2	DIST. SYSTEM, COAXIAL CABLE	12.180	0.0	0.0	0.0	12.180
1.1.2.5.3	DIST. SYSTEM, DEVICES	7.770	0.259	0.0	0.259	8.029

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1.1.2.6	MAINTENANCE	55.846	5.933	0.0	5.933	61.779
1.1.2.6.1	MAINTENANCE - FREE FLYERS	28.784	0.576	0.0	0.576	29.360
1.1.2.6.2	GANTRY CRANE	0.220	0.000	0.0	0.000	0.220
1.1.2.6.3	ON-CRANE CONTROL CENTER	26.782	5.356	0.0	5.356	32.139
1.1.2.6.4	TRACKS & ACCESS WAYS	0.060	0.000	0.0	0.000	0.060
1.1.3	INFORMATION MGMT. & CONTROL	163.189	1.632	0.0	1.632	164.821
1.1.3.1	MASTER CONTROL COMPUTER	2.659	0.027	0.0	0.027	2.685
1.1.3.2	DISPLAYS & CONTROLS	0.453	0.005	0.0	0.005	0.458
1.1.3.3	SUPERVISORY COMPUTER	0.969	0.010	0.0	0.010	0.979
1.1.3.4	REMOTE COMPUTER	2.238	0.022	0.0	0.022	2.260
1.1.3.5	BUS CONTROL UNIT	5.128	0.051	0.0	0.051	5.179
1.1.3.6	MICROPROCESSORS	5.085	0.051	0.0	0.051	5.136
1.1.3.7	REMOTE ACQUISITION & CONTROL	5.505	0.055	0.0	0.055	5.560
1.1.3.8	SUBMULTIPLEXORS	58.682	0.587	0.0	0.587	59.268
1.1.3.9	INSTRUMENTATION	65.846	0.658	0.0	0.658	66.504
1.1.3.10	OPTICAL FIBER	0.578	0.006	0.0	0.006	0.584
1.1.3.11	CABLES/HARNESS	16.047	0.160	0.0	0.160	16.207
1.1.4	ATTITUDE CONTROL & STATIONKEEPING	53.746	0.537	0.132	0.669	54.416
1.1.4.1	ACSS HARDWARE	53.746	0.537	0.047	0.584	54.330
1.1.4.2	ACSS PROPELLANT	0.0	0.0	0.085	0.085	0.085
1.1.5	COMMUNICATIONS	0.0	0.0	0.0	0.0	0.0
1.1.5.1	SATELLITE TO GROUND	0.0	0.0	0.0	0.0	0.0
1.1.5.2	SATELLITE TO RESUPPLY VEHICLES	0.0	0.0	0.0	0.0	0.0
1.1.5.3	SATELLITE INTERCOM	0.0	0.0	0.0	0.0	0.0
1.1.6	INTERFACE	102.929	1.157	0.078	1.235	104.163
1.1.6.1	STRUCTURE	68.860	0.138	0.0	0.138	68.998
1.1.6.1.1	PRIMARY STRUCTURE	6.000	0.012	0.0	0.012	6.012
1.1.6.1.2	SECONDARY STRUCTURE	62.860	0.126	0.0	0.126	62.986
1.1.6.2	MECHANISMS - INTERFACE	5.821	0.058	0.078	0.136	5.958
1.1.6.3	POWER DISTRIBUTION	6.510	0.014	0.0	0.014	6.524
1.1.6.3.1	CONDUCTOR & INSULATION	5.068	0.0	0.0	0.0	5.068
1.1.6.3.2	SLIP RING BRUSHES	1.442	0.014	0.0	0.014	1.456
1.1.6.4	THERMAL CONTROL	0.0	0.0	0.0	0.0	0.0
1.1.6.5	MAINTENANCE	21.738	0.946	0.0	0.946	22.684
1.1.6.5.1	MAINTENANCE - FREE FLYERS	6.420	0.642	0.0	0.642	7.062

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1.1.6.5.2	MANNED MANIPULATOR	15.198	0.304	0.0	0.304	15.502
1.1.6.5.3	TRACKS & ACCESS WAYS	0.120	0.000	0.0	0.000	0.120
1.1.7	SYSTEMS TEST	0.0	0.0	0.0	0.0	0.0
1.1.7.1	SYSTEM GROUND TEST HARDWARE	0.0	0.0	0.0	0.0	0.0
1.1.7.2	SYSTEM GROUND TEST OPERATIONS	0.0	0.0	0.0	0.0	0.0
1.1.8	GROUND SUPPORT EQUIPMENT	0.0	0.0	0.0	0.0	0.0
1.1.9	COTV - PRECURSOR	0.0	0.0	0.0	0.0	0.0
1.1.9.1	COTV PRECURSOR VEHICLE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.1	PRIMARY STRUCTURE - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.2	SECONDARY STRUCTURE - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.3	CONCENTRATOR - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.4	SOLAR BLANKET -E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.5	SWITCHGEAR & CONVERTERS -E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.6	CONDUCTORS & INSULATION - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.7	ACS HARDWARE - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.8	SLIPRINGS - PRECURSOR	0.0	0.0	0.0	0.0	0.0
1.1.9.1.9	PRIMARY STRUCTURE - INTERFACE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.10	SECONDARY STRUCTURE - INTERFACE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.11	MECHANISMS - INTERFACE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.12	CONDUCTORS & INSULATION	0.0	0.0	0.0	0.0	0.0
1.1.9.1.13	SLIPRING BRUSHES - PRECURSOR	0.0	0.0	0.0	0.0	0.0
1.1.9.1.14	PRIMARY STRUCTURE - POWER TRANS	0.0	0.0	0.0	0.0	0.0
1.1.9.1.15	SECONDARY STRUCTURE - POWER TRANS	0.0	0.0	0.0	0.0	0.0
1.1.9.1.16	TRANSMITTER SUBARRAYS - KLYSTRONS IC	0.0	0.0	0.0	0.0	0.0
1.1.9.1.17	SWITCHGEAR & CONVERTERS - P.T. PRECU	0.0	0.0	0.0	0.0	0.0
1.1.9.1.18	CONDUCTORS & INSULATION - P.T. PRECU	0.0	0.0	0.0	0.0	0.0
1.1.9.1.19	BATTERIES - P.T. PRECURSOR	0.0	0.0	0.0	0.0	0.0
1.1.9.1.20	THERMAL CONTROL - INSULATION - PRECU	0.0	0.0	0.0	0.0	0.0
1.1.9.1.21	REFERENCE FREQUENCY GENERATOR - PREC	0.0	0.0	0.0	0.0	0.0
1.1.9.1.22	DIST. SYSTEM, COAXIAL CABLE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.23	DIST. SYSTEM DEVICES	0.0	0.0	0.0	0.0	0.0
1.1.9.1.24	TRANSMITTER SUBARRAYS - KLYSTRONS DD	0.0	0.0	0.0	0.0	0.0
1.1.9.2	COTV PRECURSOR OPERATIONS	0.0	0.0	0.0	0.0	0.0
1.2	SPACE CONSTRUCTION & SUPPORT	1148.332	51.428	11.274	62.701	1211.033
1.2.1	CONSTRUCTION FACILITIES	123.606	19.081	11.274	30.355	153.961

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1.2.1.1	WORK SUPPORT FACILITIES	66.025	13.784	11.274	25.057	91.083
1.2.1.1.1	BEAM MACHINE	1.386	0.0	0.594	0.594	1.980
1.2.1.1.2	BEAM MACHINE CASSETTES	0.097	0.000	0.090	0.091	0.188
1.2.1.1.3	CABLE ATTACHMENT MACHINE	0.470	0.0	0.144	0.144	0.614
1.2.1.1.4	REMOTE MANIPULATOR	0.987	0.036	1.925	1.961	2.948
1.2.1.1.5	BLANKET DISPENSER MACHINE	0.436	0.0	0.180	0.180	0.616
1.2.1.1.6	SOLAR BLANKET CASSETTES	0.273	0.000	0.115	0.116	0.389
1.2.1.1.7	REFLECTOR DISPENSER MACHINE	0.078	0.0	0.048	0.048	0.126
1.2.1.1.8	REFLECTOR CASSETTES	0.042	0.001	0.054	0.055	0.097
1.2.1.1.9	CABLE/CATENARY DISPENSER MACHINES	0.380	0.0	0.168	0.168	0.548
1.2.1.1.10	ANTENNA PANEL INS. EQPT.	3.338	0.0	6.755	6.755	10.093
1.2.1.1.11	GANTRY/CRANES	1.417	0.0	0.600	0.600	2.017
1.2.1.1.12	CARGO STORAGE DEPOTS	0.126	0.0	0.600	0.600	0.726
1.2.1.1.13	FAB FIXTURE	1.374	0.0	0.0	0.0	1.374
1.2.1.1.14	AIRLOCK DOCKING MODULE (ADM)	4.038	0.285	0.0	0.285	4.323
1.2.1.1.15	BASE MGMT. MODULE (BMM)	20.231	6.069	0.0	6.069	26.300
1.2.1.1.16	POWER MODULE (PM)	17.924	5.377	0.0	5.377	23.302
1.2.1.1.17	PRESSURIZED STORAGE MODULE (PSM)	13.428	2.014	0.0	2.014	15.442
1.2.1.2	CREW SUPPORT FACILITIES-SCB	43.171	5.297	0.0	5.297	48.469
1.2.1.2.1	AIRLOCK DOCKING MODULE-ADM	1.224	0.294	0.0	0.294	1.517
1.2.1.2.2	CREW HABITABILITY MODULE-CHM	27.241	1.923	0.0	1.923	29.164
1.2.1.2.3	CONSUMABLES LOGISTICS MODULE-CLM	10.078	1.344	0.0	1.344	11.422
1.2.1.2.4	SHIELDING	0.353	0.026	0.0	0.026	0.379
1.2.1.2.5	CREW SUPPORT MODULE-CSM	4.276	1.711	0.0	1.711	5.987
1.2.1.3	OPERATIONS	14.410	0.0	0.0	0.0	14.410
1.2.1.3.1	OPERATIONS, CONSTRUCTION CREW	9.890	0.0	0.0	0.0	9.890
1.2.1.3.2	ORBITAL OPERATIONS,CONST. PROV.	4.519	0.0	0.0	0.0	4.519
1.2.2	LOGISTICS SUPPORT FACILITIES-LEO	16.340	18.299	0.0	18.299	34.640
1.2.2.1	WORK SUPPORT FACILITIES	9.770	11.724	0.0	11.724	21.494
1.2.2.1.1	BASE MGMT. MODULE-BMM	5.180	6.216	0.0	6.216	11.397
1.2.2.1.2	POWER MODULE-PM	4.590	5.507	0.0	5.507	10.097
1.2.2.2	CREW SUPPORT FACILITIES	5.480	6.576	0.0	6.576	12.055
1.2.2.2.1	CREW HABITABILITY MODULE-CHM	1.699	2.039	0.0	2.039	3.737
1.2.2.2.2	CONSUMABLES LOGISTICS MODULE	1.168	1.402	0.0	1.402	2.570
1.2.2.2.3	CREW SUPPORT MODULE/EVA	2.613	3.135	0.0	3.135	5.748

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS **	TOTAL
1.2.2.3	OPERATIONS	1.091	0.0	0.0	0.0	1.091
1.2.2.3.1	LEO OPERATIONS CREW	0.749	0.0	0.0	0.0	0.749
1.2.2.3.2	LEO CREW PROVISIONS	0.342	0.0	0.0	0.0	0.342
1.2.3	O&M SUPPORT FACILITIES - SATELLITE	1008.386	14.047	0.0	14.047	1022.433
1.2.3.1	WORK SUPPORT FACILITIES	692.183	7.778	0.0	7.778	699.960
1.2.3.1.1	AIRLOCK DOCKING MODULE-ADM	40.056	0.267	0.0	0.267	40.323
1.2.3.1.2	BASE MGMT MODULE-BMM	283.322	5.666	0.0	5.666	288.989
1.2.3.1.3	PRESSURIZED STORAGE MODULE-PSM	368.805	1.844	0.0	1.844	370.649
1.2.3.2	CREW SUPPORT FACILITIES	313.476	6.270	0.0	6.270	319.745
1.2.3.2.1	AIRLOCK DOCKING MODULE-ADM	13.774	0.275	0.0	0.275	14.049
1.2.3.2.2	CREW HABITABILITY MODULE-CHM	92.913	1.858	0.0	1.858	94.771
1.2.3.2.3	CONSUMABLES LOGISTICS MODULE-CLM	63.895	1.278	0.0	1.278	65.173
1.2.3.2.4	CREW SUPPORT MODULE/EVA	142.894	2.858	0.0	2.858	145.751
1.2.3.3	OPERATIONS	2.727	0.0	0.0	0.0	2.727
1.2.3.3.1	SATELLITE OPERATIONS CREW	1.872	0.0	0.0	0.0	1.872
1.2.3.3.2	SATELLITE CREW PROVISIONS	0.855	0.0	0.0	0.0	0.855
1.3	TRANSPORTATION	1949.004	119.343	80.869	200.212	2149.216
1.3.1	SPS-HEAVY LIFT LAUNCH VEHICLE(HLLV)	1256.406	99.642	39.372	139.014	1395.420
1.3.1.1	SPS-HLLV FLEET	767.020	99.642	24.256	123.898	890.917
1.3.1.2	SPS-HLLV OPERATIONS	489.387	0.0	15.116	15.116	504.502
1.3.2	CARGO ORBITAL TRANSFER VEHICLE(COTV)	210.343	1.957	6.371	8.328	218.671
1.3.2.1	COTV VEHICLES	205.681	1.957	6.233	8.190	213.871
1.3.2.1.1	PRIMARY STRUCTURE	0.566	0.005	0.017	0.023	0.589
1.3.2.1.2	SECONDARY STRUCTURE	142.934	1.364	4.331	5.696	148.630
1.3.2.1.3	CONCENTRATOR	0.914	0.009	0.028	0.036	0.951
1.3.2.1.4	SOLAR BLANKET	20.077	0.192	0.608	0.800	20.878
1.3.2.1.5	SWITCHGEAR AND CONVERTERS	0.465	0.001	0.014	0.016	0.481
1.3.2.1.6	CONDUCTORS AND INSULATION	0.525	0.002	0.016	0.017	0.542
1.3.2.1.7	ACS HARDWARE	40.199	0.384	1.218	1.602	41.801
1.3.2.1.8	INFO. MGMT. AND CONTROL	0.0	0.0	0.0	0.0	0.0
1.3.2.2	COTV OPERATIONS	4.662	0.0	0.139	0.139	4.801
1.3.3	PERSONNEL LAUNCH VEHICLE(PLV)	423.752	12.995	32.927	45.922	469.674
1.3.3.1	STS-PLV FLEET	188.433	12.995	14.047	27.042	215.474
1.3.3.1.1	STS-PLV ORBITER	100.340	5.797	8.250	14.047	114.387
1.3.3.1.2	STS-PLV EXTERNAL TANK	41.679	0.0	3.330	3.330	45.010

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS **	TOTAL
1.3.3.1.3	STS-PLV LIQ. ROCKET BOOSTER	33.991	7.198	2.466	9.664	43.655
1.3.3.1.4	STS CARGO CARRIER AND EM	12.423	0.0	0.0	0.0	12.423
1.3.3.2	PLV & STS-HLLV OPERATIONS	235.319	0.0	18.880	18.880	254.200
1.3.3.2.1	PLV OPERATIONS	216.507	0.0	18.880	18.880	235.387
1.3.3.2.2	STS HLLV CARGO OPERATIONS	18.813	0.0	0.0	0.0	18.813
1.3.4	PERSONNEL ORBITAL TRANS VEHICLE	2.488	0.736	0.254	0.990	3.478
1.3.4.1	POTV-FLEET	1.802	0.736	0.185	0.921	2.723
1.3.4.2	POTV-OPERATIONS	0.686	0.0	0.069	0.069	0.755
1.3.5	PERSONNEL MODULE(PM)	1.294	0.199	0.126	0.324	1.618
1.3.5.1	PM FLEET	0.746	0.199	0.075	0.273	1.019
1.3.5.2	PM OPERATIONS	0.548	0.0	0.051	0.051	0.599
1.3.6	INTRAORBITAL TRANSFER VEHICLE(IOTV)	1.471	0.265	0.045	0.310	1.780
1.3.6.1	IOTV FLEET	1.389	0.265	0.042	0.307	1.697
1.3.6.2	IOTV OPERATIONS	0.081	0.0	0.002	0.002	0.084
1.3.7	GROUND SUPPORT FACILITIES	53.250	3.550	1.775	5.325	58.575
1.3.7.1	LAUNCH FACILITIES	0.0	0.0	0.0	0.0	0.0
1.3.7.2	RECOVERY FACILITIES	0.0	0.0	0.0	0.0	0.0
1.3.7.3	FUEL FACILITIES	0.0	0.0	0.0	0.0	0.0
1.3.7.4	LOGISTICS SUPPORT	0.0	0.0	0.0	0.0	0.0
1.3.7.5	OPERATIONS	0.0	0.0	0.0	0.0	0.0
1.4	GROUND RECEIVING STATION	3590.822	0.275	78.377	78.652	3669.474
1.4.1	SITE AND FACILITIES	188.934	0.200	0.0	0.200	189.134
1.4.1.1	LAND AND PREPARATION	99.119	0.0	0.0	0.0	99.119
1.4.1.1.1	LAND	35.000	0.0	0.0	0.0	35.000
1.4.1.1.2	LAND PREPARATION	64.119	0.0	0.0	0.0	64.119
1.4.1.2	ROADS AND FENCES	74.138	0.0	0.0	0.0	74.138
1.4.1.2.1	RAILS AND ROADS	73.710	0.0	0.0	0.0	73.710
1.4.1.2.2	FENCING	0.428	0.0	0.0	0.0	0.428
1.4.1.3	UTILITIES	0.200	0.0	0.0	0.0	0.200
1.4.1.4	BUILDINGS	11.477	0.0	0.0	0.0	11.477
1.4.1.4.1	STORAGE,MAINTENANCE	1.300	0.0	0.0	0.0	1.300
1.4.1.4.2	CONV. STA. & MONITOR/CONTROL FAC.	10.177	0.0	0.0	0.0	10.177
1.4.1.5	MAINTENANCE EQPT.	4.000	0.200	0.0	0.200	4.200
1.4.1.6	LIGHTNING PROTECTION	0.0	0.0	0.0	0.0	0.0
1.4.1.7	SITE & FACILITIES DDT&E	0.0	0.0	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1.4.2	RECTENNA SUPPORT STRUCTURE	1827.999	0.075	0.447	0.522	1828.521
1.4.2.1	STEEL PANEL FAB. & INSTALLATION	1696.493	0.0	0.0	0.0	1696.493
1.4.2.1.1	HAT SECTIONS	359.224	0.0	0.0	0.0	359.224
1.4.2.1.2	WIDE FLANGES	295.170	0.0	0.0	0.0	295.170
1.4.2.1.3	TUBE BRACES & HARDWARE	431.343	0.0	0.0	0.0	431.343
1.4.2.1.4	ASSEMBLY & INSTALLATION	610.756	0.0	0.0	0.0	610.756
1.4.2.2	TRENCHING & CONCRETE INSTALLATION	131.506	0.075	0.447	0.522	132.027
1.4.2.2.1	FOOTING CONCRETE & RE-BAR	70.820	0.0	0.0	0.0	70.820
1.4.2.2.2	MACHINGERY & EQUIPMENT	0.745	0.075	0.447	0.522	1.267
1.4.2.2.3	CONSTRUCTION OPERATIONS	59.940	0.0	0.0	0.0	59.940
1.4.2.3	SUPPORT STRUCTURE DDT&E	0.0	0.0	0.0	0.0	0.0
1.4.3	POWER COLLECTION	1353.200	0.0	0.0	0.0	1353.200
1.4.3.1	ANTENNA ARRAY ELEMENTS	1127.321	0.0	0.0	0.0	1127.321
1.4.3.2	POWER DISTRIBUTION SYSTEM	69.659	0.0	0.0	0.0	69.659
1.4.3.3	INSTALLATION & CHECKOUT	156.220	0.0	0.0	0.0	156.220
1.4.3.4	POWER COLLECTION-DDT&E	0.0	0.0	0.0	0.0	0.0
1.4.4	CONTROL	75.000	0.0	0.0	0.0	75.000
1.4.4.1	CONTROL CENTER EQUIPMENT	15.000	0.0	0.0	0.0	15.000
1.4.4.2	CONTROL ELECTRONICS	60.000	0.0	0.0	0.0	60.000
1.4.4.3	CONTROL DDT&E	0.0	0.0	0.0	0.0	0.0
1.4.5	GRID INTERFACE	145.690	0.0	0.0	0.0	145.690
1.4.5.1	ELECTRICAL EQUIPMENT	145.690	0.0	0.0	0.0	145.690
1.4.5.2	GRID INTERFACE-DDT&E	0.0	0.0	0.0	0.0	0.0
1.4.6	OPERATIONS	0.0	0.0	77.930	77.930	77.930
1.4.6.1	OPER. & MAINT. PERSONNEL	0.0	0.0	64.800	64.800	64.800
1.4.6.2	MAINT. MATERIAL	0.0	0.0	13.130	13.130	13.130
1.5	MANAGEMENT AND INTEGRATION	600.679	18.815	8.561	27.377	628.055
1.6	MASS CONTINGENCY	1263.413	56.405	13.927	70.332	1333.745

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1.0 SATELLITE POWER SYSTEM (SPS) PROGRAM

The program elements described in this section include all the elements of hardware, software, and activities required for the design, development, production, assembly, transportation, operations and maintenance of the Satellite Power Systems Program. Included are the satellite and ground receiving station systems as well as the necessary support systems such as space construction and assembly equipment, plus transportation.

Cost estimates are presented for DDT&E, Theoretical First Unit (TFU), investment per satellite, replacement capital investment, and operations/ maintenance for SPS program elements in the following categories:

- Satellite
- Space Construction and Support
- Transportation
- Ground Receiving Station
- Management and Integration
- Mass Contingency

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1.1 SATELLITE

Elements of the satellite costed in this section include the hardware and software located in geosynchronous orbit for the collection of solar energy, its conversion to electrical energy, and the transmission of this electrical energy in microwave form to earth.

The satellite concept is of a planar array using GaAlAs photovoltaic cells with a solar reflector (concentrator) to provide a concentration ratio of 2.0 suns. The concept consists of 3 main bays with 10 subsections in each of the main bays and is 16,000 meters long by 3900 meters wide with an end mounted antenna adding another 1750 meters to the length (Figure 1.1-1). The total dry weight of the satellite is 26.416×10^6 kg (Table 1.1-1). It has a primary structure of composites, GaAlAs solar cells, and a microwave antenna using the klystron power module as a source for the generation of MW energy.

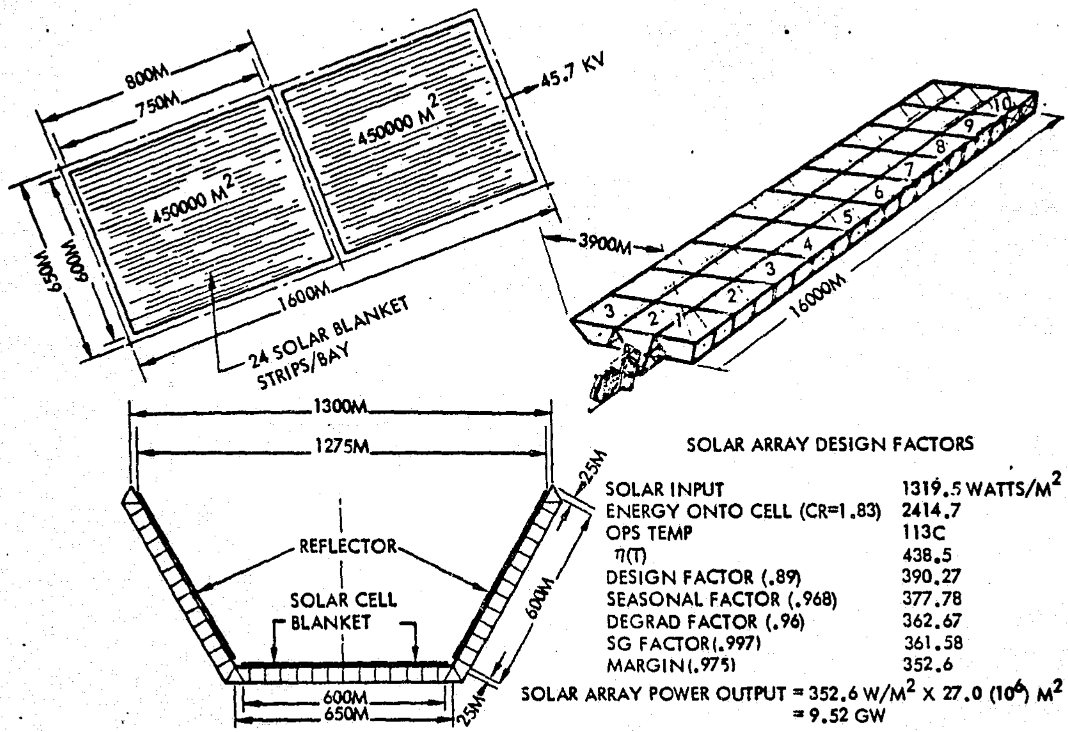

Figure 1.1-1. Solar Array Dimensions

The satellite has been divided into a number of main elements that are included in the following items as described in the SPS-WBS of Appendix A.

1.1.1 Energy Conversion

1.1.2 Power Transmission

1.1.3 Information Management and Control

1.1.4 Attitude Control and Stationkeeping

1.1.5 Communications

1.1.6 Interface

1.1.7 Systems Test

1.1.8 Ground Support Equipment

1.1.9 Precursor Test Article

Table 1.1-1. Solar Photovoltaic Power Conversion Mass Statement - ~10^6 kg End-Mounted Antenna

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SUBSYSTEM	CO-PLANAR (3 TROUGH)
COLLECTOR ARRAY	
STRUCTURE AND MECHANISMS	1.260
PRIMARY STRUCTURE	.702
SECONDARY STRUCTURE	.358
MECHANISM	.200
ATTITUDE CONTROL	(0.116)
POWER SOURCE	(7.855)
SOLAR PANELS	6.818
SOLAR REFLECTORS	1.037
POWER DISTRIBUTION AND CONTROL	(2.603)
POWER CONDITIONING EQUIPMENT	(.193)
POWER DISTRIBUTION	(2.410)
CONDUCTORS AND INSULATION	(2.367)
SLIP RINGS	.043
INFORMATION MANAGEMENT & CONTROL	(.050)
DATA PROCESSING	.021
INSTRUMENTATION	.029
TOTAL ARRAY, DRY	11.884
ANTENNA SECTION	
STRUCTURE & MECHANISM	(0.977)
PRIMARY STRUCTURE	.120
SECONDARY STRUCTURE	.599
ANTENNA	.067
MECHANISM	.191
THERMAL CONTROL	1.408
KLYSTRON COOLING	.851
INSULATION	.557
RADIATOR	-
MICROWAVE POWER	(7.012)
KLYSTRONS	4.250
ATT. SEN. ELECTRONICS & PHASE CONTROL	.142
WAVEGUIDES	2.620
POWER DISTRIBUTION & CONTROL	(4.505)
POWER CONDITIONING EQUIPMENT	1.901
POWER DISTRIBUTION	(2.604)
CONDUCTOR & INSULATION	(2.587)
SLIP RING BRUSHES	.017
INFORMATION MANAGEMENT & CONTROL	(.630)
DATA PROCESSING	.380
INSTRUMENTATION	.250
TOTAL ANTENNA SECTION	14.532
TOTAL SPS DRY	26.416

1.1.1 ENERGY CONVERSION

This element includes the components required to collect solar energy, convert the solar energy to electrical energy, condition the electrical energy, and transport it to the interface subsystem (WBS No. 1.1.6).

The satellite structure, solar cells/blankets, concentrators, and power distribution/conditioning subsystems are included in this element plus the necessary maintenance requirements to support operations.

1.1.1.1 STRUCTURE

This element includes all necessary members to support the concentrators, solar blankets, and other energy conversion subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures which are required as an interface between the primary structure and the mounting attach points of components, assemblies, and subsystems.

1.1.1.1.1 Primary Structure

The primary SPS structure assemblies are made up, basically, of tribeam girders, tension cables, and joints. The fabrication and assembly of these structures are accomplished on orbit by beam machines and supporting auxiliary equipment. These structural elements are made of a graphite fiber reinforced composite that must individually withstand the forces, torques, and dynamics imposed by the construction process. Once built into an assembly level, the structure must have sufficient strength and stiffness to withstand the forces of the environment (gravity-gradient torques), the attitude control system (forces and frequencies), and the operational equipment (rotary jointsk microwave induced thermal environment).

The SPS requirement for low thermal distortion, under high thermal stress, dictates the need for a material with a very low coefficient of expansion. The most likely candidate, at this time, is a graphite composite material.

The energy conversion structure D&D CER was developed using graphite composite data obtained from NASA's Redstar Data Base. Tooling cost was excluded under the assumption that this cost would be incurred in the development of orbital fabrication equipment. The following data points were used:

- Space Telescope Shell
- ATS-F Truss
- HEAO Optical Bench
- Shuttle Payload Bay Doors

The primary structure ICI is the cost of raw materials only since the costs associated with fabrication and assembly are charged against orbital assembly and support equipment. The structure ICI cost equation is based on raw composite material stock (prepregnated graphite) cost. These material costs are based on vendor quotes obtained from Hercules, Fiberrite and Union Carbide.

Range of Data

D&D: 30.0 to 2000.0 kg
ICI: Unlimited

1.1.1.1.2 Secondary Structure

The secondary structure consists of the passive interface attachment between the primary structure and operational subsystems. The structural members are made of aluminum with the ability to articulate, rotate, or otherwise support/allow motion between the primary structure and other subsystem elements.

This element includes all structure, consisting of mounting brackets, clamps and installation structure required as an interface and mounting attach points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies.

Development of the secondary structure CER for DDT&E was based on cost data contained in the MSFC Redstar Data Base. Data from a variety of launch vehicle and unmanned satellite programs were available and the applicable data points are listed below:

- S-IVB Interstage
- S-IC Forward Skirt
- X-IC Intertank
- Solar Telescope Housing Assembly (ASM)
- Common Mount Assembly ASM)
- Telescope Gimbal Assembly (ASM)
- Common Mount Actuators (ASM)
- Telescope Gimbal Actuators (ASM)
- Array Platform Elevation Pointing Actuator (ASM)
- UV Gimbal Mount Actuators (ASM)
- UV Instrument Mount Assembly (ASM)
- Solar Array and Boom Structure (ATS-F)
- Squib Interface Unit (ATS-F)
- Interstage (Centaur)
- Nose Shroud (Centaur)
- Fixed Airlock Shroud (Skylab)
- Payload Shroud (Skylab)
- Pallet Segment (Spacelab)
- OSO-1
- ATS-F
- S-II

The ICI production cost CER was based upon an Engineering Cost estimate.

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

Input parameters T&M are in kilograms of mass.

1.1.1.1.3 <u>Cost Estimates</u>

Table 1.1.1.1.1 and 1.1.1.1.2 cover cost estimates associated with the primary and secondary structures.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.1.1 PRIMARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	702000.000	TF=	1.000000	CDCER=	0.023000
M=	11700.0000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			47.821
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.585
#RM =T / M		60.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			35.100
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			35.100
CIPS=CTB*Z4/Z2			35.100
CRCI =CTB X R			0.070
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	358000.000	TF=	0.007300		CDCER=	0.156000
M=	5.000000	O&M=	0.0		CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000		CICER=	0.101000
PHI=	0.980000	Z2=	60.000000		CIEXP=	0.355000
R=	0.002000	Z3=	60.000000			
DF=	0.050000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			23.245
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		71600.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			69.508
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			61.689
CIPS=CTB*Z4/Z2			61.689
CRCI =CTB X R			0.123
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.1.2 CONCENTRATORS

This element concentrates the solar energy onto the solar blanket to increase the energy density on the conversion device. It includes the reflective material and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

Concentrator membranes are used to reflect the sun onto the solar cell surfaces and obtain a nominal concentration ratio of 2. The concentrator is made of (0.5-mil) aluminized Kapton. The membrane has a mass of 0.018 kg/m^2 and is mounted on the structure using attachments and tensioning devices. Excluded are tools and support equipment required for deployment.

The DDT&E CER (CD) is based on thin sheet aluminum vendor data. The ICI CER for concentrators is based on Rockwell data for Type H Kapton material with an aluminized coating. As concentrator thickness decreases, cost per unit area decreases due to the diminished material requirements. However, at around 25 microns (1 mil), the cost reductions are cancelled by the increased difficulty of processing thin materials and the overall cost per unit area begins to rise. Rockwell data from Dupont indicates that the current cost of 0.5 mil concentrator for the SPS would be about $4.73 per square meter. At increased demand and increased yields, cost could potentially reach $1.61 per square meter. However, the most likely value, and the value on which the concentrator ICI CER is based, was quoted at $2.58 per square meter. For the purposes of the CER this was rounded to $3.00 per square meter to include sensors and mounting attachments and scaled at a slope of 0.95 to reflect anticipated large array economies.

Range of Data

DDT&E: 100 M^2 – 100,000 M^2
ICI: Unlimited

Input parameters T&M are in square meters, see Table 1.1.1.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.2 CONCENTRATORS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	54000000.0	TF=	1.000000	CDCER=	0.0
M=	450000.000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000003
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.950000
R=	0.002000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.704
#RM =T / M			120.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			75.637
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))). / Z3			67.184
CIPS=CTB*Z4/Z2			67.183
CRCI =CTB X R			0.134
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.1.3 SOLAR BLANKET

This element converts solar energy to electrical energy and provides power to the power distribution and conditioning buses. It includes the photovoltaic conversion cells, cover-plates, substrate, electrical interconnects, and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

Gallium aluminum arsenide (GaAlAs) cells have been selected. The cell consists of GaAs junction with a GaAlAs window, substrate, adhesive, current collectors, and an anti-reflective coating. The solar blanket consists of a Kapton membrane upon which the cells are fastened with a thermo-setting FEP adhesive. Also included in the blanket are the interconnects, thermal coating, attachments/tensioning devices, and sensors.

Historical cost data on solar arrays from previous satellite programs were readily available from the Redstar Data Base and were used to develop the CD CER. However, due to the rapidly changing technology, historical data is not applicable for use in estimating the SPS solar blanket production cost. The Department of Energy (DOE) has initiated the U.S. Photovoltaic Conversion Program. Two main objectives of this program are to develop by 1990 the technological and industrial capability to produce silicon solar arrays at a price of less than $500 per peak KWe and to establish by 2000 the viability of even lower-cost ($100 to $300 per KWe) and/or more efficient alternatives utilizing novel materials and devices. Since it is generally believed throughout the photovoltaic industry that low cost solar arrays are achievable and dependent on the demand for high production rates and since some progress toward meeting the DOE goal has already been made, it was decided to base the SPS solar array cost estimates on projected costs rather than historical costs.

The CD CER was based on solar array historical cost data from the following programs..

- Skylab (OWS)
- Skylab (ATM)
- FRUSA
- SEPS (Est.)

The cost of array structure and mechanisms was not included so that the data would be compatible with the SPS concept of on-orbit structure fabrication and assembly. Although there is a large difference in size between the above arrays and the SPS array, the SPS array will consist of a large number of smaller units. The development fraction (DF) was utilized to normalize the CD cost to reflect cost of only that portion of the total solar array area required to develop the power system.

The initial capital investment CER (CI) cost estimate for material and production processing was based upon information contained in the Arthur D. Little report of March 1978 as prepared under Contract NAS9-15294 with NASA/JSC. The materials cost of $33/M^2$ and a fabrication cost of $34/M^2$ total $67/M^2$ for a gallium arsenide solar cell array. This assessment is consistent with work completed under Rockwell company sponsored activity based on 1977 prices and assuming 1990 technology.

Range of Data:

DDT&E: 10-300 square meters
ICI: Unlimited

Cost estimates are shown in Table 1.1.1.3.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.3 SOLAR BLANKETS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	27000000.0	TF=	1.000000	CDCER=	0.0
M=	18750.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000067
PHI=	0.990000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.256
#RM =T / M		1440.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.986	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1651.832
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1556.693
CIPS=CTB*Z4/Z2			1556.692
CRCI =CTB X R			3.113
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.1.4 POWER DISTRIBUTION AND CONDITIONING (PD&C)

This element includes the various power feeders, switching and conditioning equipments necessary to deliver power at the required voltage and power levels throughout the satellite. An energy storage system is included, as a power source, to supply minimum power to the various subsystems during eclipse periods. Data buses are not a part of this element as they are included in the information management and control subsystem (WBS No. 1.1.3).

The PD&C system receives power from the solar photovoltaic power generation system and provides for the power conditioning and switching required to deliver the power, through its distribution network, to the satellite power transmission system. Electrical power is transferred from the solar array distribution network through a rotary joint, utilizing slip rings and brushes, to the microwave antenna distribution and conditioning system for the delivery of power at the required levels. The life expectancy of the PD&C is 30 years with the exception of the energy storage system (batteries), which is projected to have a life expectancy of 15 years.

1.1.1.4.1 Switches and Converters

Switches will be used to perform various functions and will be monitored and controlled through the IMCS. Switchgears will:

- Isolate solar array blankets for maintenance work
- Provide voltage regulation of solar array output by selective switching of isolation switchgears
- Control voltage and currents through the IMCS system for short circuit protection
- Prevention of large line transients
- Systematic start-up and shut-down of array during eclipse periods
- Control various loads

The primary switches will be of the Penning cross-field tube design. Functions controlled by these switches will be monitored by the IMCS to determine their status and establish the opening or closing position as required. Basically, the switches are held in a closed state during the operational mode. During start-up and shut-down operations, switches will be monitored by the IMCS, and when certain voltage levels are reached, a command signal will open or close switches as needed.

The power converter and conditioners convert the existing bus voltages to the subsystem voltage required for the various subsystem loads. The output tolerances will be based on the using subsystem interface requirements. The power converters are utilized in the GEO mode of operation.

1.1.1.4.2 Conductors and Insulation

Main feeders are generally sized to minimize the combined mass of itself and the solar array mass, considering power requirements, efficiency, and the variation in resistivity with operating temperature. The power distribution system utilizes flat aluminum (6101/T6) feeders where feasible, and round conductors for those subsystems where flat conductors are not feasible.

The CD CER was based on historical cost data obtained from the Redstar Data Base on the following satellite programs.

- DSCS-II
- ATS-F
- OSO-I
- ATS-B
- ATS-A
- ATS-E
- HEAO

The ICI CER was based on preprocessed aluminum material cost data and the use of 6101/T6 aluminum. Differential aluminum inflation between current prices and expected mid 1986 prices was included. Cost data was obtained from the following manufacturers:

- Reynolds Metals
- Alcoa Aluminum
- Amchem Products, Inc.
- The Yoder Company

Range of Data:

DDT&E: 20 to 150 kilograms
ICI: Unlimited

1.1.1.4.3 Slip Rings

The slip ring portion of the rotary joint is included in the PD&C of the Energy Conversion segment. The slip rings consist of an aluminum core with coin silver cladding on each slip ring. The core cross section is 33.7 cm^2. The slip ring diameter is .3 km with a length of .94 km. Each slip ring weighs 10,715 kg with a total weight of 42,860 kg for the required 4 slip rings.

The cost data for the slip rings cost data are based upon large ground commercial and military slip rings. Since all but one of the base data slip rings were designed for ground application, it was decided that these data should not be used as a basis for estimating DDT&E costs. It was determined that the data should be used only as a basis for estimating ICI production costs and then only after applying complexity and specification uprating factors. The following factors were applied:

Complexity Factor	× 3
Specification Uprating Factor	× 3
Total	× 9

The ICI production cost CER was based on data provided by the following manufacturers.

Manufacturer	Application
Poly-Scientific	High energy
Poly-Scientific	Radar
Electro-Tec	Navy destroyer propeller system
Electro-Tec	Satellite solar array
I.E.C.	Navy shipboard hoist

Due to the relatively low production rate of 1 to 5 units per year, the tooling factor is assumed to be 1.0.

The DDT&E cost was estimated with a CER developed for secondary structure which consisted of space qualified hardware of approximately the same complexity. See the discussion of the secondary structure CER.

Range of Data.

1.1.1.4.4 Batteries

Batteries will be utilized during ecliptic periods to provide minimum energy required by the energy conversion subsystems. The batteries will be of a sodium chloride design, having a density of at least 200 watt hours/kg.

The DDT&E and the ICI CER's were developed using battery data from the manned/unmanned spacecraft list below:

- APOLLO Lunar Module
- APOLLO Lunar Rover
- ATS-E
- ATS-F
- HAWKEYE
- OSO-I

Range of Data:

DDT&E: 1.0 to 180.0 kg
ICI: 1.0 to 180.0 kg

1.1.1.4.5 Battery PD&C

This element provides the mechanism for the charging of the satellite batteries and the distribution and regulation of power to and from the batteries. Included are the battery chargers, power regulators, power conditioning and power conditioning equipment which directly interface with the battery subsystem.

The DDT&E and the ICI CER's were developed using data from the manned and unmanned spacecraft below:

- APOLLO Lunar Module
- APOLLO Lunar Rover
- GEMINI
- HAWKEYE

- ATS-E
- ATS-F
- OSO-I

Range of Data:

DDT&E: 2.0 to 68.0 kg
ICI: 2.0 to 68.0 kg

1.1.1.4.6 PD&C Cost Estimates

Cost calculations developed from the CER's discussed in the preceding paragraphs are presented in the following tables:

Table	Description
1.1.1.4.1	Switch Gear and Converters
1.1.1.4.2	Conductors and Insulation
1.1.1.4.3	Slip Rings
1.1.1.4.4	Batteries
1.1.1.4.5	Battery PD&C

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.1 SWITCH GEAR & CONVERTERS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	187000.000	TF=	1.000000	CDCER=	0.158000
M=	3117.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.500000	Z1=	1.000000	CICER=	0.000400
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.582
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.870
#RM =T / M		59.994	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			89.123
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			66.093
CIPS=CTB*Z4/Z2			66.093
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.2 CONDUCTORS & INSULATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2367000.00	TF=	1.000000	CDCER=	0.158000
M=	19725.0000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	0.100000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			6.234
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.079
#RM =T / M		120.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.468
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			9.468
CIPS=CTB*Z4/Z2			9.468
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.3 SLIP RINGS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	43000.0000	TF=	1.000000	CDCER=	0.156000
M=	10750.0000	O&M=	0.0	CDEXP=	0.511000
CF=	1.500000	Z1=	1.000000	CICER=	0.000764
PHI=	0.900000	Z2=	60.000000	CIEXP=	0.950000
R=	0.010000	Z3=	60.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.392
CLRM=CICER X (M)XX(CIEXP) X CF X TF			7.745
#RM =T / M		4.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.848	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			27.626
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			15.825
CIPS=CTB*Z4/Z2			15.825
CRCI =CTB X R			0.158
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.4 BATTERIES

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	4000.00000	TF=	0.075600			CDCER=	0.037000
M=	50.000000	O&M=	0.010000			CDEXP=	0.734000
CF=	1.000000	Z1=	1.000000			CICER=	0.028000
PHI=	0.950000	Z2=	60.000000			CIEXP=	0.241000
R=	0.033333	Z3=	120.000000				
DF=	0.200000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			5.001
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.005
#RM =T / M		80.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.338
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.238
CIPS=CTB*Z4/Z2			0.238
CRCI =CTB X R			0.008
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.010

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.5 BATTERY PD&C

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2000.00000	TF=	0.043000	CDCER=	0.053000
M=	250.000000	O&M=	0.0	CDEXP=	0.890000
CF=	1.000000	Z1=	1.000000	CICER=	0.012000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.859000
R=	0.010000	Z3=	60.000000		
DF=	0.500000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			24.790
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.059
#RM =T / M		8.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.430
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.324
CIPS=CTB*Z4/Z2			0.324
CRCI =CTB X R			0.003
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.1.5 THERMAL CONTROL

This element includes any component used to modify the temperature of the energy conversion subsystem components. It includes cold plates, heat transfer and radiator devices as well as insulation, thermal control coatings and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence.

1.1.1.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

The maintenance requirements of this element are related to the energy conversion section of the satellite covering the main structure, concentrators, solar blankets, and power distribution/conditioning. Some of the items of maintenance equipment will be commonly used on the satellite power transmission and interface segments. In these cases, the costs have been apportioned to the related WBS element. Maintenance requirements are listed in Table 1.1.1.6 and costs are presented in Tables 1.1.1.6.1, 1.1.1.6.2 and 1.1.1.6.3.

Table 1.1.1.6 Maintenance Requirements

WBS NO.	MAINTENANCE ITEM DESCRIPTION	1.1.1.6 ENERGY CONVERSION
1.1.1.6.1	"Free-Flyers" or Barge for Cargo and Personnel (Common Use Item)	0.8 Vehicle Utilization
1.1.1.6.2	Manned Manipulator Module	1 Vehicle
1.1.1.6.3	Tracks and Access Ways	84,000 kg

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.6.1 MAINTENANCE - FREE FLYERS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000	CDCER=	0.0
M=	5000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.250000	Z1=	0.800000	CICER=	0.005798
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	48.000000		
DF=	1.000000	Z4=	48.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			36.238
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			29.299
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			29.240
CIPS=CTB*Z4/Z2			23.392
CRCI =CTB X R			0.585
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.6.2 MANNED MANIPULATOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	3000.00000	TF=	1.000000	CDCER=	0.0
M=	3000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.100000	Z1=	1.000000	CICER=	0.005798
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			19.133
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			19.203
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			15.198
CIPS=CTB*Z4/Z2			15.198
CRCI =CTB X R			0.304
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.6.3 TRACKS & ACCESS WAYS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	84000.0000	TF=	1.000000	CDCER=	0.0
M=	84000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000005
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.420
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.420
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.420
CIPS=CTB*Z4/Z2			0.420
CRCI =CTB X R			0.001
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2 MW POWER TRANSMISSION

This element receives dc electrical power from the interface subsystem, conditions the power, converts it to microwave energy and radiates the energy to the ground receiving station. Included are power distribution from the interface subsystem, dc to RF conversion devices, control and monitoring equipment, and antenna radiating elements.

Costs in this section include those of the antenna structure and subarrays with their klystrons; the power distribution and conditioning system; thermal control; phase reference system; and maintenance requirements. The MW antenna system is illustrated in Figure 1.1-2 and illustrates the basic configuration, including overall dimensions of the selected antenna structure concept.

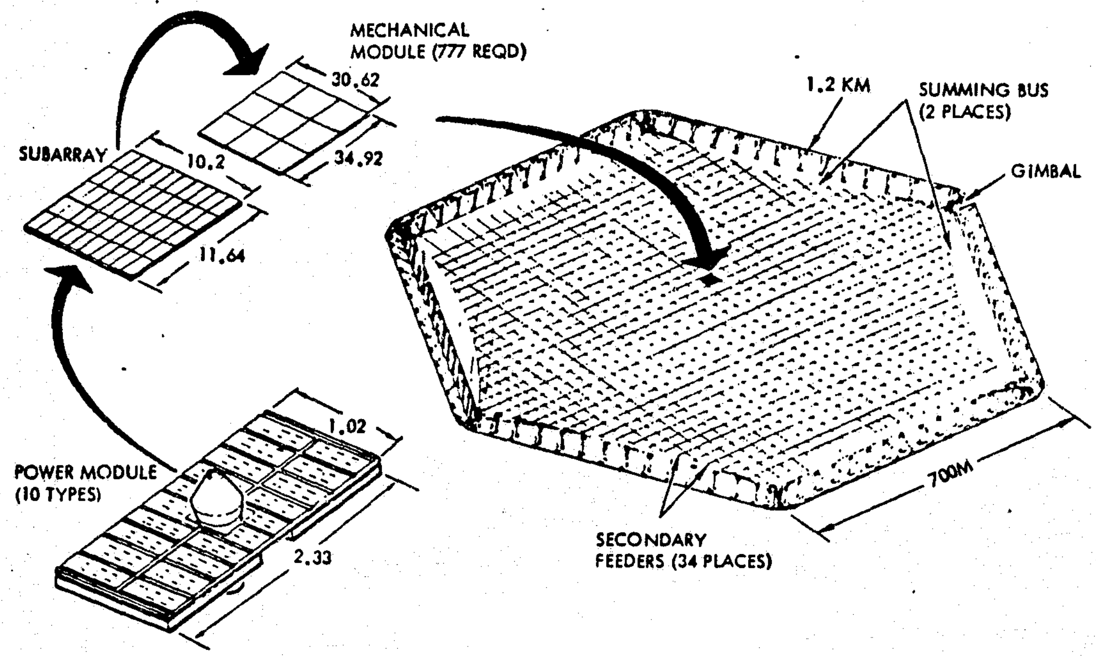

Figure 1.1-2. Microwave Transmission System - Satellite Antenna

The smallest antenna building block is the power module, which varies in size from the one illustrated (which is used at the center portion of the antenna) to 3.40 by 5.82 meters at the periphery of the antenna. Ten different power module sizes are used to comprise the antenna element. Each power module has a klystron located in its center. The power modules are arranged into subarrays measuring 10.2 by 11.64 meters. Each subarray has its own phase control electronics. Nine subarrays are connected to form a mechanical module 30.82 by 34.92 meters.

1.1.2.1 STRUCTURE

This element includes all members necessary to support the transmitter subarrays and other power transmission subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures.

1.1.2.1.1 Primary Structure

This element includes the basic supporting framework of the microwave antenna power transmission system up to the interface connection. The antenna primary structure has three main components - a tension web made from composite wires or tapes; a catenary cable that transfers the web tension to the verticies; and the octogonal compression frame. The antenna frame provides a structural support but does not include the wave guides or radio frequency assemblies associated with the microwave subsystem.

This element is limited to primary load carrying structure and does not include other secondary structure such as equipment mounts, platforms, and space equipment supports.

The SPS requirement for low thermal distortion, under high thermal stress, dictates the need for a material with a very low coefficient of expansion. The most likely candidate, at this time, is a graphite composite material.

The antenna structure D&D CER was developed using graphite composite data obtained from NASA's Redstar Data Base. Tooling cost was excluded under the assumption that this cost would be incurred in the development of orbital fabrication equipment. The following data points were used:

- Space Telescope Shell
- ATS-F Truss
- HEAO Optical Bench
- Shuttle Payload Bay Doors

The antenna structure ICI is the cost of raw materials only since the costs associated with fabrication and assembly are charged against orbital assembly and support equipment. The antenna structure ICI cost equation is based on raw composite material stock (prepregnated graphite) cost. These material costs are based on vendor quotes obtained from Hercules, Fiberrite and Union Carbide.

Range of Data:

D&D: 30,0 to 2000.0 kg
ICI: Unlimited

1.1.2.1.2 Secondary Structure

The secondary structure consists of the passive interface attachment between the primary structure and operational subsystems. The structural members are made of aluminum with the ability to articulate, rotate, or

otherwise support/allow motion between the primary structure and other subsystem elements.

This element includes all structure, consisting of mounting brackets, clamps and installation structure required as an interface and mounting attach points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies.

Development of the secondary structure CER for DDT&E was based on cost contained in the MSFC Redstar Data Base. Data from a variety of launch vehicle and unmanned sate-lite programs were available and the applicable data points are listed below:

- S-IVB Interstage
- S-IC Forward Skirt
- S-IC Intertank
- Solar Telescope Housing Assembly (ASM)
- Common Mount Assembly (ASM)
- Telescope Gimbal Assembly (ASM)
- Common Mount Actuators (ASM)
- Telescope Gimbal Actuators (ASM)
- Array Platform Elevation Pointing Actuator (ASM)
- UV Gimbal Mount Actuators (ASM)
- UV Instrument Mount Assembly (ASM)
- Solar Array and Boom Structure (ATS-F)
- Squib Interface Unit (ATS-F)
- Interstage (Centaur)
- Nose Shroud (Centaur)
- Fixed Airlock Shroud (Skylab)
- Payload Shroud (Skylab)
- Pallet Segment (Spacelab)
- OSO-1
- ATS-F
- S-II

The ICI production cost CER was based upon an Engineering Cost estimate.

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

1.1.2.1.3 Cost Estimates

Input parameters T&M are in kilograms of mass, see Tables 1.1.2.1.1 and 1.1.2.1.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.1.1 PRIMARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	67000.0000	TF=	1.000000	CDCER=	0.023000
M=	8375.00000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.301
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.419
#RM =T / M		8.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			3.350
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			3.350
CIPS=CTB*Z4/Z2			3.350
CRCI =CTB X R			0.007
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	234000.000	TF=	0.007300	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.002000	Z3=	60.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			18.705
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		46800.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			45.999
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			40.825
CIPS=CTB*Z4/Z2			40.825
CRCI =CTB X R			0.082
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2.2 TRANSMITTER SUBARRAY/KLYSTRONS

This element includes all the hardware required for generation, distribution, phase control and radiation of microwave energy. This includes the subarray structure, wave guides, power amplifiers, control devices, and power harnesses. Also included are thermal control devices and finishes that are manufactured as an integral part of the subarray.

RF generators convert the direct current (dc) electric power to RF microwave power. Klystrons are used in this system as the high power RF transmitting devices. Wave guides receive the RF power from the generator and radiate it to the ground-based rectenna.

Historical data for some twenty phased array radars ranging over a period of the last twenty years were extracted from the Redstar Data Base and/or obtained from various contractors. The data were analyzed, normalized and the costs were adjusted to reflect 1977 dollars. In addition, for all costs utilized, the facility receiver subsystem hardware, data subsystem costs and basic facility/housing costs were removed.

The application of phased array radar costs to the development cost estimates of the microwave antenna was pertinent since the design and development of these physically large ground installations was conducted in much the same manner that is being utilized for the SPS. The ground array radiating elements were assembled in subarray panels, complete with the radiating elements, wave guide, and cabling. The subarrays were then mounted into the facility framework, subarray cabling, and plumbing connection completed at system level and confidence testing conducted. The same general assembly philosophy is expected to be followed for the microwave antenna, the difference being that the microwave antenna will be totally assembled in the space environment.

The D&D CER was based on data from four DOD classified projects identified only as Projects 21, 22, 23, and 24 as well as the Cobra Dane, AN/SPS-48 and SAM-D (PATRIOT) radar systems.

A different approach was taken to develop the TFU CERs. After reviewing the various radar systems' cost, it was determined that not enough insight was afforded into the components; therefore, a "grass-roots" approach was undertaken.

For purposes of developing a "grass-roots" estimate for the TFU, a segment of the antenna measuring 2.4 m^2 was assumed to be the Lowest Replaceable Unit (LRU). In addition, to arrive at an "average" LRU, it was necessary to evenly distribute all components over the antenna. Enclosed tables list the components and their estimated cost for both the klystron and amplitron configurations. The required components were determined through analysis. Letters and telephone calls were directed to hardware manufacturers requesting technical data and cost quotes for the specified components. Where multiple quotes were obtained, the average cost was used. In some instances, estimates had to be relied upon. It was further assumed that the components are the same in each configuration with only the power tubes changing with the exception of the klystron configuration where the IRF amplifier is different.

Data contained in the Redstar Data Base were utilized to develop integration factors which were added to the vendor quotes. To account for the cost associated with voltage measurement instrumentation for the microwave antenna, a 20% instrument factor was also applied to the vendor quotes. The individual cost estimates, developed for each type of power tube, were utilized to develop CERs based on the area of one LRU. For the purpose of developing these CERs, three different LRU sizes were assumed - 2.4 m^2, 24 m^2, and 240 m^2. It is necessary for the user to determine the size and number of LRUs required for any given antenna configuration. It is also necessary for the user to consider any learning that may occur.

Range of Data:

D&D: 1000 to 100,000 kilowatts
ICI: Unlimited

Table 1.1.2.2.1 expresses the DDT&E cost estimate [C_D=.067$(P_T)^{0.507}$(CF)] to facilitate the use of antenna power in kilowatts as the input factor. Table 1.1.2.2.2 shows the $C_{I,LRU}$=.00327$(A_{LRU})^{1.000}$ where A is in square meters. A complexity factor of 1.25 is used to compensate for the klystron kilowatt power rating as used in the data base.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.2.1 KLYSTRON DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	6790000.00	TF=	1.000000	CDCER=	0.205000
M=	6790000.00	O&M=	0.0	CDEXP=	0.507000
CF=	1.250000	Z1=	1.000000	CICER=	0.0
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	180.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KW	SUM TO 1.1.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			102.576
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.2.2 KLYSTRON ICI, R, O&M

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	830808.000	TF=	1.000000	CDCER=	0.0
M=	118.800003	O&M=	0.0	CDEXP=	0.0
CF=	1.250000	Z1=	1.000000	CICER=	0.003270
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	180.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.486
#RM =T / M	6993.332		
E =1.0 + LOG(PHI) / LOG(2.0)	0.971		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2702.309
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2322.804
CIPS=CTB*Z4/Z2			2322.804
CRCI =CTB X R			154.854
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2.3 POWER DISTRIBUTION AND CONDITIONING (PD&C)

This element includes the various power feeders, switching, and conditioning equipment s necessary to deliver power at the required voltage and power levels for the power transmission section (antenna portion) of the satellite. An energy storage system is included to supply power to keep the power transmission system at a ready state and for housekeeping requirements during eclipse periods. Data buses are not a part of this element as they are included in the information management and control subsystem (WBS No. 1.1.3).

The PD&C system receives power from the interface (Energy Conversion/ Power Transmission) system and provides for the power conditioning and switching required to deliver the power, through the distribution network, to the microwave energy conversion units. On the rotating member, power is conducted through switch gears to dc/dc converters which output the six primary voltages required by the Klystrons. Each voltage is conducted to a summing bus through switch gears and power feeders and on through switch gear at the mechanical modules for use at the subarrays to provide power at the 135,864 Klystrons.

Batteries and battery conditioning equipment are included also to provide the stored energy to power the heater requirements which keep the Klystrons at a ready mode during the eclipse periods. The batteries will also provide power for the necessary housekeeping activities, i.e., stationkeeping, IMCS, TT&C, etc., during this period.

1.1.2.3.1 Switches and Power Conditioning

Switches will be used to perform operational functions as monitored through the IMCS. Switch gears will:

- Isolate converters, main feeders, secondary feeders, mechanical modules, subarrays and Klystrons for maintenance work

- Provide split bus power feed to offer redundancy to some modules in event of failure of a converter or summing bus

- Control power through the IMCS for:
  - short circuit protection
  - systematic start-up and shut-downs to prevent surges during eclipse periods
  - control various loads

The basic switches will be of the Penning cross-field tube design and monitored and controlled by the IMCS. The IMCS will will determine their status and functionally connect them to the proper feeder and summing bus as conditions may direct.

The power converter and conditioners convert the existing bus voltages to the subsystem voltage required for the various subsystem loads. The output tolerances will be based on using subsystem interface requirements. The power converters are utilized in the GEO mode of operation.

1.1.2.3.2 Conductors and Insulation

The summing buses, main feeders and secondary feeders are generally sized to minimize the combined mass of itself and the satellite mass, considering the power requirements, efficiency, and variation in resistivity with temperature. The PD&C utilized aluminum (6101-T6) conductors.

1.1.2.3.3 Batteries

Batteries will be utilized during the ecliptic periods to provide minimum energy to keep the Klystrons warmed to a ready state and as necessary during the required housekeeping tasks. The batteries will be a sodium chloride type having the capability of providing 200 watt hours/kg.

The battery PD&C costing is included in the earlier sections of 1.1.2.3.2 and 1.1.2.3.1. This element consists of the mechanisms for the charging of batteries and the distribution and regulation of power to and from the battery. This function will be monitored and controlled by the IMCS. Included are the battery chargers, power regulators, diodes, power regulators, and power conditioning equipment that directly interfaces with the battery system.

1.1.2.3.4 PD&C Cost Estimates

The CER's used in this section are the same as those described in Section 1.1.1.4. The following tables itemize the design/cost parameters and identify the cost estimates in each area.

Table	Description
1.1.2.3.1	Switch Gear and Converters
1.1.2.3.2	Conductors and Insulation
1.1.2.3.3	Batteries

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.3.1 SWITCH GEAR & CONVERTERS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1901000.00	TF=	1.000000	CDCER=	0.158000
M=	2447.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.500000	Z1=	1.000000	CICER=	0.000400
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	180.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.132
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.468
#RM =T / M		776.870	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			752.336
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			512.556
CIPS=CTB*Z4/Z2			512.556
CRCI =CTB X R			34.171
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.3.2 CONDUCTORS & INSULATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1337000.00	TF=	1.000000	CDCER=	0.158000
M=	1720.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	0.100000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			5.262
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.007
#RM =T / M		777.325	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			5.348
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.348
CIPS=CTB*Z4/Z2			5.348
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.3.3 BATTERIES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	190000.000	TF=	0.075600	CDCER=	0.0
M=	50.000000	O&M=	0.475000	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.028000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.241000
R=	0.033333	Z3=	120.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.005
#RM =T / M			3800.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			12.115
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			8.502
CIPS=CTB*Z4/Z2			8.502
CRCI =CTB X R			0.283
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.475

COMMENTS

BATTERY PD&C INCLUED IN 1.1.2.3.1 & 1.1.2.3.2

ORIGINAL PAGE IS OF POOR QUALITY

1.1.2.4 THERMAL CONTROL

This element includes any component used to modify the temperature of power transmission subsystem components. It includes cold plates, heat transfer and radiator devices as well as insulation, thermal control coatings and finishes. Excluded are paints and finishes applied to components during during their manufacturing sequence and thermal control devices that are an integral part of another component.

The multi-layer insulation panels are required for the back surface of the resonant cavity radiators to restrict waste heat leaks which could increase temperatures of electronics to unacceptable levels. This insulation is coated externally with low absorptivity/emissivity materials to limit the absorbed solar flux to which the surface is exposed during part of the orbit.

The insulation CER's are based upon secondary structure CER's where the secondary structure CER's were considered comparable to the requirements of insulation in its application on the antenna.

Table 1.1.2.4 presents cost estimates for thermal control.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.4 THERMAL CONTROL - INSULATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	557000.000	TF=	0.012400	CDCER=	0.156000
M=	4.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.010000	Z3=	60.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			29.136
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.002
#RM =T / M		139250.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			208.062
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			184.657
CIPS=CTB*Z4/Z2			184.657
CRCI =CTB X R			1.847
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2.5 CONTROL-PHASE REFERENCE

This element provides the reference phase for all subarray phase conjugating circuits and includes the reference oscillator signal distribution, and frequency conversion equipment. It covers components/equipment that commonly serve all subarrays.

The transmitted signal is formed from the pilot beam by means of the retroelectronics where one circuit is required per subarray. A servo system is needed to transfer the required reference phase from a central point to a mechanical module, where it is distributed to the nine subarrays. The main items included in this subsystem are shown in Table 1.1.2.5.

Table 1.1.2.5 Control-Phase Reference

WBS NO.	ITEM/ DESCRIPTION	QUANTITY PER SATELLITE
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	1 SET (777 POWER AMPLIFIERS, 1-4 REGULATORS)
1.1.2.5.2	COAX CABLE	777 SETS
1.1.2.5.3	DEVICES FOR USE ON FREQUENCY DISTRIBUTION SYSTEM	777 SETS

Tables 1.1.2.5.1, 1.1.2.5.2 and 1.1.2.5.3 present the engineering estimates for these items.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.5.1 REFERENCE FREQUENCY GENERATOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.500000
M=	1.000000	O&M=	0.010000	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.100000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.033333	Z3=	120.000000		
DF=	0.200000	Z4=	60.000000	Z5 =	0.0

CALCULATED VALUES - SET SUM TO 1.1.2.5		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.100
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.100
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.100
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.100
CIPS=CTB*Z4/Z2		0.100
CRCI =CTB X R		0.003
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.010

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.5.2 DIST. SYSTEM, COAXIAL CABLE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	203000.000	TF=	1.000000	CDCER=	0.000005
M=	261.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.000060
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	M	SUM TO 1.1.2.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.203
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.016
#RM =T / M	777.778		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			12.180
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			12.180
CIPS=CTB*Z4/Z2			12.180
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.5.3 DIST. SYSTEM, DEVICES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1554.00000	TF=	1.000000	CDCER=	0.000225
M=	2.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.005000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.033333	Z3=	120.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.070
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.010
#RM =T / M		777.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.770
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			7.770
CIPS=CTB*Z4/Z2			7.770
CRCI =CTB X R			0.259
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and insitu repair equipment.

Maintenance requirements of this element are related to the power transmission (antenna) section of the satellite covering the structures; subarrays (Klystrons); power distribution/conditioning and energy storage; thermal control, and control elements. Some of the maintenance equipment are multipurpose and are therefore costed against the applicable maintenance items on an apportioned basis.

Maintenance requirements for this element are presented in Table 1.1.2.6 and cost estimates are projected in Tables 1.1.2.6.1, 1.1.2.6.2, 1.1.2.6.3, and 1.1.2.6.4.

Table 1.1.2.6 Maintenance Requirements

WBS NO.	MAINTENANCE ITEM DESCRIPTION	1.1.2.6 POWER TRANSMISSION
1.1.2.6.1	"FREE-FLYERS" OR BARGE FOR CARGO AND PERSONNEL (COMMON USE ITEM)	1 VEHICLE UTILIZATION
1.1.2.6.2	GANTRY CRANE AT ANTENNA	SET
1.1.2.6.3	ON-CRANE CONTROL CENTER, HOISTS, EQUIPMENT TEST GEAR, ROBOTICALS	SET
1.1.2.6.4	TRACKS AND ACCESSWAYS	12000 kg

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.6.1 MAINTENANCE - FREE FLYERS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000			CDCER=	0.0
M=	5000.00000	O&M=	0.0			CDEXP=	0.0
CF=	1.250000	Z1=	1.000000			CICER=	0.005798
PHI=	0.950000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.2.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			36.238
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			36.368
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			28.784
CIPS=CTB*Z4/Z2			28.784
CRCI =CTB X R			0.576
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.6.2 GANTRY CRANE

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	40000.0000	TF=	1.000000	CDCER=	0.234000
M=	40000.0000	O&M=	0.0	CDEXP=	0.653000
CF=	1.100000	Z1=	1.000000	CICER=	0.000005
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			91.060
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.220
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.220
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.220
CIPS=CTB*Z4/Z2			0.220
CRCI =CTB X R			0.000
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.6.3 ON-CRANE CONTROL CENTER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	50000.0000	TF=	1.000000	CDCER=	0.012432
M=	50000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	0.100000	CICER=	0.005798
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	6.000000		
DF=	1.000000	Z4=	6.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			621.600
CLRM=CICER X (M)XX(CIEXP) X CF X TF			289.900
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			30.305
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			267.824
CIPS=CTB*Z4/Z2			26.782
CRCI =CTB X R			5.356
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.6.4 TRACKS & ACCESS WAYS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	12000.0000	TF=	1.000000	CDCER=	0.0
M=	12000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000005
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.060
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.060
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.060
CIPS=CTB*Z4/Z2			0.060
CRCI =CTB X R			0.000
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

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1.1.3 INFORMATION MANAGEMENT AND CONTROL

This element includes those components that process information onboard the satellite. This includes sensing, signal conditioning, formatting, computations, and signal routing.

The information management and control subsystem (IMCS) provides the interconnecting elements between and within all the various satellites and ground-based operational subsystems. The IMCS also provides operational control of both the satellite and ground systems as well as providing all subsystem processing support for all but very special functions.

The satellite IMCS consists of the on-board processing equipment [central processing units (CPU) and memories], the inter- and intra-subsystem data network (data buses), the man-machine interfaces (display/control), and intersystem communication links, including RF, but excepting those specifically provided for the control and transfer of primary power, and all elements provided to accommodate activities related to system security, safety, or any other operation necessary to the continuing operation of the SPS.

Because of the early stage of program analysis, only those requirements imposed upon the IMCS by a limited number of satellite operations have been identified. The identified requirements generally are limited to those associated with the immediate operations of an active satellite. Auxiliary functions such as ground/space communications, display/control, safety, security, etc., will be added when data become available.

The usage and application of IMCS items is identified in Table 1.1-3 and provides direct association with the subsystem functions.

Table 1.1-3. Usage/Application Matrix per Satellite

	INSTRUMENTATION		DATA ACQUISITION		DATA PROCESSING				CONTROL		
ELEMENT DESCRIPTION	SENSORS	SIGNAL CONDITIONING	SOFTWARE	SIGNAL ROUTING	SOFTWARE	FORMATTING	COMPUTATION	DISPLAY GENERATION	DISPLAYS & CONTROLS	SIGNAL CONDITIONING	WBS NO.
MASTER CONTROL COMPUTER					X	X	X	X			1.1.3.1
DISPLAYS CONTROL					X	X	X	X	X		1.1.3.2
SUPERVISORY COMPUTER					X	X	X				1.1.3.3
REMOTE COMPUTER					X	X	X				1.1.3.4
BUS CONTROL UNIT			X	X	X	X	X				1.1.3.5
MICROPROCESSORS					X	X	X				1.1.3.6
REMOTE ACQ. & CONTROL			X	X	X	X	X			X	1.1.3.7
SUB-MULTIPLEXER			X	X	X	X	X				1.1.3.8
INSTRUMENTATION	X	X									1.1.3.9
FIBER OPTICS				X							1.1.3.10
CABLES & HARNESSES	X	X	X	X	X	X	X	X	X	X	1.1.3.11

These items have been separated into general hardware groups for costing purposes.

COMPUTERS

Historical cost data were obtained for computers from the Redstar Data Base system and are listed below:

- Gemini-3
- Minuteman
- Skylab
- Viking Lander
- MOL
- HEAO

A 50% integration factor was included in the DDT&E CER's to allow for subsystem level costs.

Range of Data:

DDT&E and ICI: 1.8 to 75.7 kilograms

ELECTRONIC COMPONENTS

The electronic components associated with Avionics include the Submultiplexors, Remote Acquisition Units, Microprocessors, Bus Control Units and instrumentation.

Development of an electronic components CER was based on the selected components of the ATS-F and OSO-8 spacecraft. These 19 electronic components are listed below:

ATS-F	OSO-8
Aux. Digital Sun Sensors	Solar Power Supply
Monopulse Unit	Power Supply
Wide Band Data Unit	Control Decoder/Demodulator
C Band Data Unit	Remote Decoder
S/L Band Transmitter	PCM Decoder
VHF Receiver	Format Generator
Command Decoder	Wheel Clock
Data Acq. & Control Unit	Sail Clock
Data Switching Unit	S Band Transmitter
	VHF Transmitter

Range of Data:

DDT&E and ICI: 1.1 to 19.6 kilograms

DATA BUS

This element consists of both copper wire and fiber optics. Historical cost data were obtained from the Redstar Data Base to produce the data bus DDT&E CER. Commercial prices were used for the data bus ICI CER.

Production cost information obtained from private industry for "off-the-shelf" fiber optics and copper wire are listed below:

FIBER OPTICS:

Manufacturer	Type	Characteristics	Cost per Meter
ITT Electro-Optical Products Division	GG-02	Single Fiber 50 m Dia.	(1-10 km) $3.25
	GS-02	Single Fiber 50 m Dia.	$2.50
Valtec Fiberoptics Division	MG-05	Single Fiber 65 m Dia.	$2.50
Galileo Electro-Optics Corporation	-	Single Fiber 88 m Dia.	$1.58
		Average cost per meter	$2.40

One industry spokesman estimates that the cost of optical fibers would likely decrease to 40% by 1980. This study assumes a $2.40 per meter average price reduced by 40% to $1.44 per meter.

COPPER WIRE:

Manufacturer	Characteristics	Cost per Meter
Dearborn Wire & Cable	22 gage stranded silver plate	$0.807
Standard Wire & Cable	22 gage stranded silver plate	$0.705
Karen, Inc.	22 gage, 2 conductor silver plate	$0.807
Mil-Spec Wire & Cable Corporation	22 gage, 19-30 stranded	$0.610
	Average cost per meter	$0.732

Instrumentation input parameters T&M are in kilograms.

Cost estimates for the items of Table 1.1-3 are presented in Tables 1.1.3.1 through 1.1.3.11 inclusive.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.1 MASTER CONTROL COMPUTER

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1000.00000	TF=	0.900000			CDCER=	0.633000
M=	500.000000	O&M=	0.0			CDEXP=	0.521000
CF=	1.000000	Z1=	1.000000			CICER=	0.172000
PHI=	0.800000	Z2=	60.000000			CIEXP=	0.535000
R=	0.010000	Z3=	60.000000				
DF=	0.500000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			16.127
CLRM=CICER X (M)XX(CIEXP) X CF X TF			4.302
#RM =T / M		2.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.678	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.845
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2.659
CIPS=CTB*Z4/Z2			2.659
CRCI =CTB X R			0.027
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.2 DISPLAYS & CONTROLS

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	200.000000	TF=	0.900000		CDCER=	0.102000
M=	200.000000	O&M=	0.0		CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000		CICER=	0.069000
PHI=	0.800000	Z2=	60.000000		CIEXP=	0.557000
R=	0.010000	Z3=	60.000000			
DF=	1.000000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			10.745
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.188
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.678	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.211
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.453
CIPS=CTB*Z4/Z2			0.453
CRCI =CTB X R			0.005
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.3 SUPERVISORY COMPUTER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	84.000000	TF=	0.700000	CDCER=	0.633000
M=	14.000000	O&M=	0.0	CDEXP=	0.521000
CF=	1.000000	Z1=	1.000000	CICER=	0.172000
PHI=	0.850000	Z2=	60.000000	CIEXP=	0.535000
R=	0.010000	Z3=	60.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.753
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.494
#RM =T / M		6.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.766	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.325
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.969
CIPS=CTB*Z4/Z2			0.969
CRCI =CTB X R			0.010
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.4 REMOTE COMPUTER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	518.000000	TF=	0.400000	CDCER=	0.633000
M=	14.000000	O&M=	0.0	CDEXP=	0.521000
CF=	1.000000	Z1=	1.000000	CICER=	0.172000
PHI=	0.850000	Z2=	60.000000	CIEXP=	0.535000
R=	0.010000	Z3=	60.000000		
DF=	0.030000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.643
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.282
#RM =T / M		37.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.766	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			5.696
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2.238
CIPS=CTB*Z4/Z2			2.238
CRCI =CTB X R			0.022
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.5 BUS CONTROL UNIT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	4110.00000	TF=	0.076000	CDCER=	0.102000
M=	5.000000	O&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000	CICER=	0.069000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.557000
R=	0.010000	Z3=	60.000000		
DF=	0.001200	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.415
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.013
#RM =T / M		822.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.940
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.128
CIPS=CTB*Z4/Z2			5.128
CRCI =CTB X R			0.051
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.6 MICROPROCESSORS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	3960.00000	TF=	0.078000	CDCER=	0.102000
M=	5.000000	O&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000	CICER=	0.069000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.557000
R=	0.010000	Z3=	60.000000		
DF=	0.001300	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.431
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.013
#RM =T / M		792.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.881
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.085
CIPS=CTB*Z4/Z2			5.085
CRCI =CTB X R			0.051
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.7 REMOTE ACQUISITION & CONTROL

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	4925.00000	TF=	0.069000	CDCER=	0.102000
M=	5.000000	O&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000	CICER=	0.069000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.557000
R=	0.010000	Z3=	60.000000		
DF=	0.001000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.414
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.012
#RM =T / M		985.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.450
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.505
CIPS=CTB*Z4/Z2			5.505
CRCI =CTB X R			0.055
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.8 SUBMULTIPLEXORS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	93000.0000	TF=	0.022000	CDCER=	0.102000
M=	3.000000	O&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000	CICER=	0.069000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.557000
R=	0.010000	Z3=	60.000000		
DF=	0.000032	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.266
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.003
#RM =T / M		31000.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			66.119
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			58.682
CIPS=CTB*Z4/Z2			58.682
CRCI =CTB X R			0.587
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.9 INSTRUMENTATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	280000.000	TF=	1.000000	CDCER=	0.000100
M=	0.074100	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.000400
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.010000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			28.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.000
#RM =T / M		3778676.00	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			74.192
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			65.846
CIPS=CTB*Z4/Z2			65.846
CRCI =CTB X R			0.658
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.10 OPTICAL FIBER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	62.000000	TF=	1.000000	CDCER=	0.237000
M=	62.000000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.010219
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.010000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.807
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.634
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.634
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.578
CIPS=CTB*Z4/Z2			0.578
CRCI =CTB X R			0.006
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.11 CABLES/HARNESS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	293000.000	TF=	1.000000	CDCER=	0.237000
M=	293000.000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000060
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.010000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5 =	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			9.963
CLRM=CICER X (M)XX(CIEXP) X CF X TF			17.580
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			17.604
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			16.047
CIPS=CTB*Z4/Z2			16.047
CRCI =CTB X R			0.160
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.4 ATTITUDE CONTROL AND STATIONKEEPING

This element includes the components required to orient and maintain the satellite's position and attitude in geosynchronous orbit. Included are sensors, reaction wheels, chemical and electric propulsion hardware and propellants.

The baseline ACSS features an argon ion bombardment thruster RCS whose characteristics are:

- Thrusters located in 4 modules at each corner of the satellite
- Each module has 16 thrusters
- Cryogenic propellant storage-electric refrigeration with heat loss makeup
- Hemispherical plume characteristics
- Serviceable in place

The system operates on an average of 36 thrusters. A total of 64 thrusters are included to provide the required redundancy. The redundancy was based on an annual maintenance/servicing interval, 5000 hour thruster grid lifetime and 5-year thruster MTBF. Sixteen thrusters are located on the lower portion of each corner of the spacecraft. Each thruster is gimbaled individually to facilitate thruster servicing, to permit operation of adjacent thrusters during servicing, and to provide the redundancy. The thrusters nominally provide a force approximately in the direction of the sun to counter the solar pressure force (stationkeeping) which is the dominant thruster requirement. The thrusters are gimbaled through small angles (as illustrated) and differentially throttled to provide the remaining forces and torques for attitude control and stationkeeping.

Sensors that make up the attitude reference determination system include:

- CDD Sun Sensor (1/System)
- CCD Star Sensors (2/Systems)
- Electrostatic or laser gyros (3/System)
- Dedicated mini processor

The attitude reference determination system features Charge Coupled Device (CCD), star and sun sensors as well as electrostatic or laser gyros and dedicated microprocessors. Seven attitude reference determination units are located at various locations on the satellite in order to sense thermal and dynamic body bending, and to desensitize the system to these disturbances. The control algorithms will feature statistical estimators for determining principal axis orientation, body bending state observers or estimators, and a quasi-linear propulsion thrust command policy to provide precise control and minimize structural bending excitation.

The mass properties of the ACSS are summarized in Table 1.1-4. This summary includes the mass of individual elements and propellant weight on an annual basis.

Table 1.1-4. ACSS Mass Summary

ITEM	MASS (x 10^{+3} KG)
ATTITUDE REFERENCE DETERMINATION SYSTEMS (7)	0.32
THRUSTERS—INCLUDING SUPPORT STRUCTURE, 64 @ 120 KG/THRUSTER	7.68
THRUSTER GIMBALS AND MOUNTING	3.98
TANKS, LINES, REFRIGERATION	15.07
POWER PROCESSING EQUIPMENT	88.95
TOTAL (DRY)	116.00
ARGON PROPELLANT—ANNUAL REQUIREMENT	85.39
TOTAL (WITH PROPELLANT)	201.39

Historical cost data were obtained from NASA's Redstar Data Base. Historical data relative to electrical propulsion is limited, consequently, study data have been utilized where necessary. Ion bombardment thrusters are Argon propellants with a low thrust but a significantly higher specific impulse, thus reducing propellant resupply cost.

Development of the propulsion subsystem CER's was based on the spacecraft programs listed below:

SEPS (Boeing) Study
SEPS (Rockwell) Study
SERT-II
ATS-F (Ion Experiment)
Rockwell SPS Study
SERT-C Study

Range of Data:

DDT&E and ICI: 18.0 to 107,500.0 kg

Input parameters T&M are in kilograms.

Tables 1.1.4.1 and 1.1.4.2 contain the costs for this element.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.4.1 ACSS HARDWARE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	116000.000	TF=	0.105900	CDCER=	1.122000
M=	1812.00000	O&M=	0.046620	CDEXP=	0.190000
CF=	1.000000	Z1=	1.000000	CICER=	0.057000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.729000
R=	0.010000	Z3=	60.000000		
DF=	0.300000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			8.183
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.432
#RM =T / M		64.018	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			72.488
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			53.746
CIPS=CTB*Z4/Z2			53.746
CRCI =CTB X R			0.537
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.047

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.4.2 ACSS PROPELLANT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.085390	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.085

COMMENTS

1.1.5 COMMUNICATIONS

This element includes the hardware to transmit and receive intelligence among the various SPS elements. It includes communication of both data and voice between the SPS and the control center, as well as among the various cargo and personnel vehicles. Excluded is intravehicular and intrasatellite communications.

1.1.6 INTERFACE (ENERGY CONVERSION/POWER TRANSMISSION)

This element provides the movable interface between the energy conversion subsystem and the power transmission subsystem. A 360° rotary joint and an antenna elevation mechanism are required to maintain proper alignment of the transmitter with the ground receiving station. Included are structure, mechanisms, power distribution, and maintenance hardware.

The interface is utilized to 1) transfer energy from the slip ring to the antenna via transmission brushes, and 2) act as the structural support member between the main satellite and the antenna. The elements of this movable interface (Figure 1.1-6) are described in the following subsections.

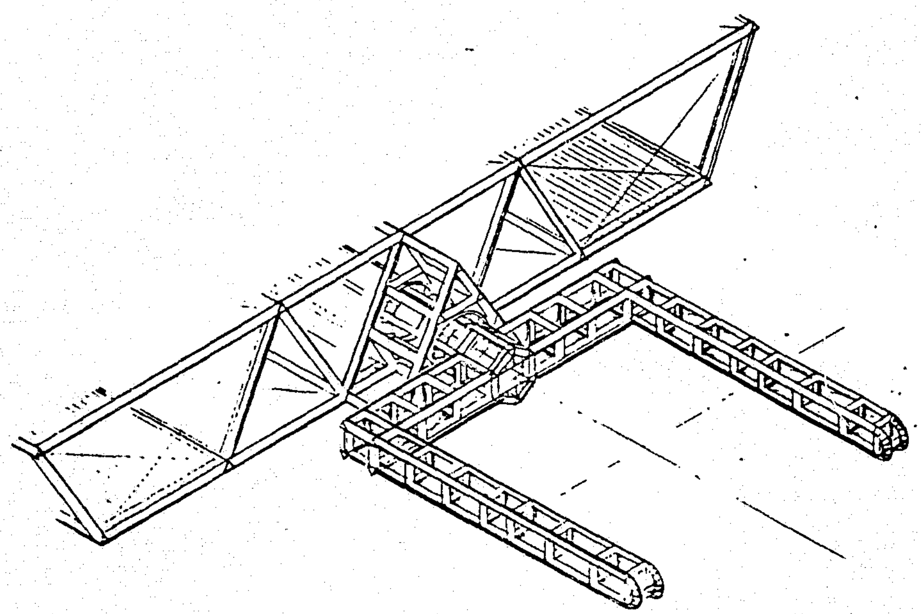

Figure 1.1-6. Energy Conversion/Power Transmission Interface

1.1.6.1 STRUCTURE

This element includes all members necessary to provide a mechanical interface between the primary structures of the energy conversion subsystem and the power transmission subsystem. It includes beams, beam couplers, cables, tensioning devices, and secondary structures. Excluded are elements of the drive assembly which are included in mechanisms (WBS No. 1.1.6.2).

1.1.6.1.1 Primary Structure

The basic supporting structure of the movable interface is included in this element. It is the primary load carrying structure and does not include the secondary structure that is required to support transmission buses or equipment.

The SPS requirement for low thermal distortion, under high thermal stress, dictates the need for a material with a very low coefficient of expansion. The most likely candidate, at this time, is a graphite composite material.

The interface primary structure D&D CER was developed using graphite composite data obtained from NASA's Redstar Data Base. Tooling cost was excluded under the assumption that this cost would be incurred in the development of orbital fabrication equipment. The following data points were used:

- Space Telescope Shell
- ATS-F Truss
- HEAO Optical Bench
- Shuttle Payload Bay Doors

The interface structure ICI is the cost of raw materials only since the costs associated with fabrication and assembly are charged against orbital assembly and support equipment. The structure ICI cost equation is based on raw composite material stock (prepregnated graphite) cost. These material costs are based on vendor quotes obtained from Hercules, Fiberrite and Union Carbide.

Range of Data:

D&D: 30.0 to 2000.0 kg
ICI: Unlimited

1.1.6.1.2 Secondary Structure

The secondary structure consists of the passive interface attachment between the primary structure and operational subsystems. The structural members are made of aluminum with the ability to articulate, rotate, or otherwise support/allow motion between the primary structure and other subsystem elements.

This element includes all structure, consisting of mounting brackets, clamps and installation structure required as an interface and mounting attach

points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies.

Development of the secondary structure CER for DDT&E was based on cost data contained in the MSFC Redstar Data Base. Data from a variety of launch vehicle and unmanned satellite programs were available and the applicable data points are listed below:

- S-IVB Interstage
- S-IC Forward Skirt
- S-IC Intertank
- Solar Telescope Housing Assembly (ASM)
- Common Mount Assembly (ASM)
- Telescope Gimbal Assembly (ASM)
- Common Mount Actuators (ASM)
- Telescope Gimbal Actuators (ASM)
- Array Platform Elevation Pointing Actuator (ASM)
- UV Gimbal Mount Actuators (ASM)
- UV Instrument Mount Assembly (ASM)
- Solar Array and Boom Structure (ATS-F)
- Squib Interface Unit (ATS-F)
- Interstage (Centaur)
- Nose Shroud (Centaur)
- Fixed Airlock Shroud (Skylab)
- Payload Shroud (Skylab)
- Pallet Segment (Spacelab)
- OSO-1
- ATS-F
- S-II

The ICI production cost CER was based upon an Engineering Cost estimate.

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

Input parameters T&M are in kilograms of mass.

1.1.6.1.3 Cost Estimates

Primary and secondary structure costs are presented in Table 1.1.6.1.1 and 1.1.6.1.2 respectively.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.1.1 PRIMARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	120000.000	TF=	1.000000	CDCER=	0.023000
M=	20000.0000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			11.638
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.000
#RM =T / M		6.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			6.000
CIPS=CTB*Z4/Z2			6.000
CRCI =CTB X R			0.012
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	365000.000	TF=	0.007300	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.002000	Z3=	60.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			23.476
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		73000.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.827
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			62.860
CIPS=CTB*Z4/Z2			62.860
CRCI =CTB X R			0.126
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.6.2 MECHANISMS

This element includes the components required to rotate and elevate the power transmission subsystem. Included are the drive ring, bearings, gear drives, and drive motors.

The structural mechanisms consist of active structural subassemblies that articulate, rotate, or otherwise cause or allow motion between the primary structure and other subsystem elements or between subsystem elements themselves.

The ICI production cost CER was based on data provided by the following manufacturers:

Manufacturer	Application
Poly-Scientific	High energy
Poly-Scientific	Radar
Electro-Tec	Navy destroyer propeller system
Electro-Tec	Satellite solar array
I.E.C.	Navy shipboard hoist

Due to the difference in complexity and the specification requirements differences between ground and space qualified equipment, the following factors were applied.

Complexity Factor	× 3
Specification Uprating Factor	× 3
Total	× 9

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

Input parameters T&M are in kilograms of mass, see Table 1.1.6.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.2 MECHANISMS - INTERFACE

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	391000.000	TF=	0.054900			CDCER=	0.156000
M=	391.000000	O&M=	0.078000			CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000			CICER=	0.000764
PHI=	0.950000	Z2=	60.000000			CIEXP=	0.950000
R=	0.010000	Z3=	60.000000				
DF=	0.020000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			15.225
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.012
#RM =T / M		1000.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.878
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.821
CIPS=CTB*Z4/Z2			5.821
CRCI =CTB X R			0.058
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.078

COMMENTS

1.1.6.3 POWER DISTRIBUTION

This element transmits the electrical power from the rotary joint to the microwave power transmission system. The PD&C system consists of power risers which are coupled to the pickup shoebrushes on the rotary joint and routed on the antenna support yolk (interface) to the isolation switches on the antenna proper. There are two sets of slip rings. One positive and one negative, at the rotary joint. Sixteen brushes are needed per slip ring. The life expectancy of the PD&C is 30 years with calculated replacements of the slip ring.

1.1.6.3.1 Conductors and Insulation

The power risers are sized to minimize the mass of itself and the satellite mass, considering power requirements, efficiency and variation in resistivity with operating temperature. The power risers are made of multiple round aluminum (6101-T6) conductors with 1 mm kapton insulation.

1.1.6.3.2 Pickup Shoe Brushes

The pickup shoe brush portion of the rotary joint is included in the power distribution of the interface segment. Sixty-four pickup shoe brush assemblies are required per satellite. The brush material is 75% M_0S_2 and 25% M_0tTa with a contact surface area per brush of 863 cm^2. The shoe dimension is 2.72 m × 12.7 am × 19 am with a total weight of 11341 kg for 64 pickup shoe brushes.

1.1.6.3.3 Power Distribution Cost Estimates

The CER presented in section 1.1.1.4.2 was used for the conductors and insulation. An extension of this CER was used for the brushes of section 1.1.6.3.2. The cost estimates for interface power distribution are presented in Tables 1.1.6.3.1 and 1.1.6.3.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.3.1 CONDUCTOR & INSULATION

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1267000.00	TF=	1.000000			CDCER=	0.158000
M=	39594.0000	O&M=	0.0			CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000			CICER=	0.000004
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	60.000000				
DF=	0.100000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.6.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			5.178
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.158
#RM =T / M		32.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			5.068
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.068
CIPS=CTB*Z4/Z2			5.068
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.3.2 SLIP RING BRUSHES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	11341.0000	TF=	1.000000	CDCER=	0.158000
M=	531.000000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000200
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.010000	Z3=	60.000000		
DF=	0.020000	Z4=	60.000000	Z5 =	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.791
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.106
#RM =T / M		21.358	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.935
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.442
CIPS=CTB*Z4/Z2			1.442
CRCI =CTB X R			0.014
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.6.4 THERMAL CONTROL

This element includes any component used to modify the temperature of interface subsystem components. It includes cold plates, heat transfer and radiator devices as well as insulation, thermal control coatings and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence. No thermal control requirements are defined for the interface.

1.1.6.5 MAINTENANCE

THis element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and insitu repair equipment.

Maintenance requirements are related to the equipment and facilities needed to transport men and material to the work station. Some of the same equipment required for maintenance at the site is used commonly in the performance of work at other sites. The CER's accommodate this usage. Table 1.1.6.5 identifies the requirements, and cost estimates are provided in Tables 1.1.6.5.1, 1.1.6.5.2, and 1.1.6.5.3.

Table 1.1.6.5 Maintenance Requirements

WBS NO.	MAINTENANCE ITEM DESCRIPTION	1.1.6.5 INTERFACE
1.1.6.5.1	"FREE-FLYERS" OR BARGE FOR CARGO AND PERSONNEL (COMMON USE ITEM)	.2 VEHICLE UTILIZATION
1.1.6.5.2	MANNED MANIPULATOR MODULE	1 VEHICLE
1.1.6.5.3	TRACKS AND ACCESS WAYS	24000 kg

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.5.1 MAINTENANCE - FREE FLYERS

INPUT PARAMETERS | | | | INPUT COEFFICIENTS

T=	5000.00000	TF=	1.000000	CDCER=	0.0
M=	5000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.250000	Z1=	0.200000	CICER=	0.005798
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	12.000000		
DF=	1.000000	Z4=	12.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			36.238
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.530
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			32.098
CIPS=CTB*Z4/Z2			6.420
CRCI =CTB X R			0.642
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.5.2 MANNED MANIPULATOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	3000.00000	TF=	1.000000	CDCER=	0.0
M=	3000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.100000	Z1=	1.000000	CICER=	0.005798
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5 =	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			19.133
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			19.203
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			15.198
CIPS=CTB*Z4/Z2			15.198
CRCI =CTB X R			0.304
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.5.3 TRACKS & ACCESS WAYS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	24000.0000	TF=	1.000000	CDCER=	0.0
M=	24000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000005
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.120
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.120
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.120
CIPS=CTB*Z4/Z2			0.120
CRCI =CTB X R			0.000
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.7 SYSTEMS TEST

This element includes the hardware, software, and activities required for ground-based systems test including qualification tests and other development tests involving two or more subsystems or assemblies. It includes the production, assembly, integration, and checkout of satellite system hardware into a full or partial system test article. It also includes the design, development, and manufacture of special test equipment, test fixtures, and test facilities that are not included in other elements such as ground support facilities. Also included are the planning, documentation, and actual test operations.

Tables 1.1.7.1 and 1.1.7.2 document DDT&E cost estimates respectively for hardware and operations based on individual calculations equal to 50% of the satellite ICI.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.7.1 SYSTEM GROUND TEST HARDWARE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5 =	0.0

CALCULATED VALUES SET	SUM TO 1.1.7	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		2662.711
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	0.0	
E =1.0 + LOG(PHI) / LOG(2.0)	0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

DDT&E = 50% OF SATELLITE ICI

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.7.2 SYSTEM GROUND TEST OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.1.7		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		2662.711
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	0.0	
E =1.0 + LOG(PHI) / LOG(2.0)	0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

DDT&E TEST OPS = 50% OF SATELLITE ICI

1.1.8 GROUND SUPPORT EQUIPMENT (GSE)

This element includes all ground-based hardware required in support of handling, servicing, test, and checkout of the satellite subsystems. It also includes special hardware required for simulations and training.

Costs for design, development, manufacture, acceptance, qualification, and maintenance of the GSE equipment are included. It is recognized that various equipments can serve multipurposes. For example, a developmental mockup may later serve as a training aid after it has served its original purposes. In these instances, the acquisition cost is charged to the original or first purpose use, and subsequent usage will incur only the recurring operations and maintenance costs.

GSE costs from several launch vehicle, manned spacecraft and unmanned satellites were analyzed to determine their applicability to SPS GSE requirements. From these data, a percentage factor was developed which was used to estimate SPS ground support equipment costs. This factor is expressed by the equation $C_D = 0.10\ (C)$; where C = DDT&E cost of the satellite system. See Table 1.1.8.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.8 GROUND SUPPORT EQUIPMENT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		721.234
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	0.0	
E =1.0 + LOG(PHI) / LOG(2.0)	0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

DDT&E GSE = 10% OF SATELLITE DDT&E ABOVE

1.1.9 PRECURSOR TEST ARTICLE

The 335 MW pilot plant precursor test article and operations is included in this element. It represents the technology verification space system combining the energy conversion, interface, and power transmission segments of the SPS satellite. The configuration will be constructed by the satellite construction base where the sequence is to build the slip ring/rotary joint housing structure followed by the interface hub and yoke base plus the 1st bay of the solar array. Slip rings are installed and the solar concerter portion is completed as the yoke (interface) arms are fabricated. The antenna construction and maintenance platform is attached to provide facilities for the antenna fabrication and installation of required power modules. The completed EOTV/Demo unit is illustrated in Figure 1.1.9.

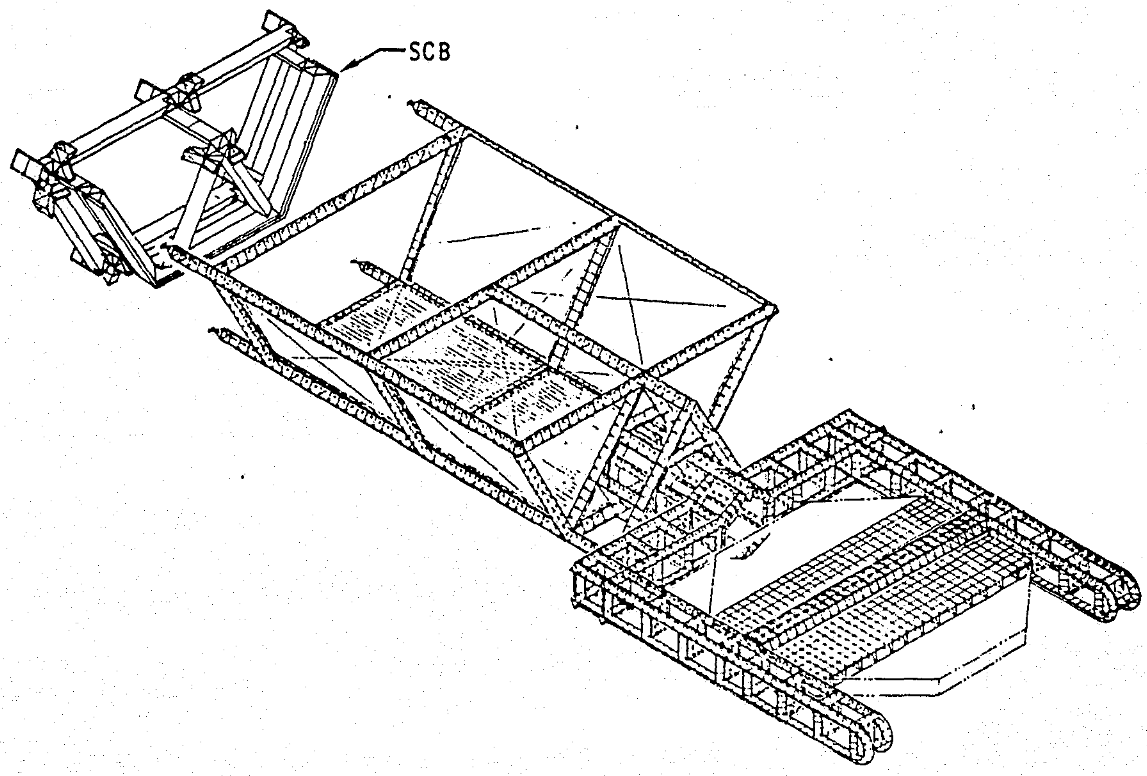

Figure 1.1.9 EOTV Precursor Test Article

1.1.9.1 EOTV PRECURSOR VEHICLE

This element covers the vehicle procurement required to support the integrated test and demonstration program.

The energy conversion segment of the vehicle consists of primary and secondary structure, concentrators, solar blankets, switchgear and converters, conductors/insulation, attitude control and information management subsystems. The interface segment includes the primary and secondary structure, mechanisms, conductors/insulation and slip ring brushes.

The precursor power transmission segment will be representative of the full-up satellite antenna to the extent of using identically available components for the required power levels of the test article. It will include structures, transmitter subarrays, power distribution and conditioning, batteries, insulation, and phase control elements.

CER's used in this section are the same as those used in the particular elements of earlier satellite sections. DDT&E is, however, a main cost item in these categories as the systems/subsystems will require substantial development activities, whereas the other satellite systems/subsystems will capitalize from this development work.

Cost estimates for the precursor test article are presented in the following tables:

Tables	Segment
1.1.9.1.1 thru 1.1.9.1.8	Energy Conversion
1.1.9.1.9 thru 1.1.9.1.13	Interface
1.1.9.1.14 thru 1.1.9.1.24	Power Transmission

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.1 PRIMARY STRUCTURE - E.C.

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	30890.0000	TF=	1.000000			CDCER=	0.023000
M=	2059.00000	O&M=	0.0			CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000			CICER=	0.000050
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			89.863
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.103
#RM =T / M	15.002		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.544
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.2 SECONDARY STRUCTURE - E.C.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	14918.0000	TF=	1.000000	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.355000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			21.178
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.179
#RM =T / M			2983.600
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			533.576
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.3 CONCENTRATOR - E.C.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1800000.00	TF=	1.000000	CDCER=	0.027000
M=	450000.000	O&M=	0.0	CDEXP=	0.394000
CF=	1.000000	Z1=	1.000000	CICER=	0.000003
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.950000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.869
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.704
#RM =T / M		4.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.817
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.4 SOLAR BLANKET -E.C.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	900000.000	TF=	1.000000	CDCER=	0.161400
M=	18750.0000	O&M=	0.0	CDEXP=	0.394000
CF=	1.000000	Z1=	1.000000	CICER=	0.000067
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	2.000000	Z4=	60.000000	Z5 =	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			47.041
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.256
#RM =T / M		48.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			60.300
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.5 SWITCHGEAR & CONVERTERS -E.C.

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	2875.00000	TF=	1.000000	CDCER=	0.158000
M=	719.000000	O&M=	0.0	CDEXP=	0.297000
CF=	1.500000	Z1=	1.000000	CICER=	0.000400
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	3.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.497
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.431
#RM =T / M		3.999	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.725
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.6 CONDUCTORS & INSULATION - E.C.

INPUT PARAMETERS

T=	357675.000	TF=	1.000000		
M=	7452.00000	O&M=	0.0		
CF=	1.000000	Z1=	1.000000		
PHI=	1.000000	Z2=	60.000000		
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

INPUT COEFFICIENTS

CDCER=	0.158000
CDEXP=	0.297000
CICER=	0.000004
CIEXP=	1.000000

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.048
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.030
#RM =T / M		47.997	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.431
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.7 ACS HARDWARE - E.C.

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	283557.000	TF=	0.300000			CDCER=	1.122000
M=	1970.00000	O&M=	0.0			CDEXP=	0.190000
CF=	1.000000	Z1=	1.000000			CICER=	0.057000
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.729000
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			12.190
CLRM=CICER X (M)XX(CIEXP) X CF X TF			4.312
#RM =T / M		143.938	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			620.634
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.8 SLIPRINGS - PRECURSOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	43000.0000	TF=	1.000000	CDCER=	0.156000
M=	10750.0000	O&M=	0.0	CDEXP=	0.511000
CF=	1.500000	Z1=	1.000000	CICER=	0.000764
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.950000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			54.565
CLRM=CICER X (M)XX(CIEXP) X CF X TF			7.745
#RM =T / M		4.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			30.980
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.9 PRIMARY STRUCTURE - INTERFACE

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	120000.000	TF=	1.000000	CDCER=	0.023000
M=	200.000000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	0.500000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			152.844
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.010
#RM =T / M		600.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.10 SECONDARY STRUCTURE - INTERFACE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	15500.0000	TF=	0.007300	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.355000
R=	0.0	Z3=	0.0		
DF=	0.500000	Z4=	60.000000	Z5 =	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			15.155
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M	3100.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			4.047
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.11 MECHANISMS - INTERFACE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	391000.000	TF=	1.000000	CDCER=	0.156000
M=	391.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.000764
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.950000
R=	0.0	Z3=	0.0		
DF=	0.500000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			78.868
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.222
#RM =T / M			1000.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			221.647
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION
TABLE 1.1.9.1.12 CONDUCTORS & INSULATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	52790.0000	TF=	1.000000	CDCER=	0.158000
M=	1650.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.993
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.007
#RM =T / M		31.994	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.211
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.13 SLIPRING BRUSHES - PRECURSOR

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	11341.0000	TF=	1.000000			CDCER=	0.158000
M=	531.000000	O&M=	0.0			CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000			CICER=	0.000200
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.529
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.106
#RM =T / M		21.358	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.268
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.14 PRIMARY STRUCTURE - POWER TRANS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000	CDCER=	0.023000
M=	1250.00000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			20.936
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.063
#RM =T / M		4.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.250
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.15 SECONDARY STRUCTURE - POWER TRANS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	9750.00000	TF=	0.007300	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.355000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			17.041
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		1950.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.546
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.16 TRANSMITTER SUBARRAYS - KLYSTRONS ICI

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	34617.0000	TF=	1.000000	CDCER=	0.0
M=	118.800003	O&M=	0.0	CDEXP=	0.0
CF=	1.250000	Z1=	1.000000	CICER=	0.003270
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.486
#RM =T / M		291.389	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			141.497
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.17 SWITCHGEAR & CONVERTERS - P.T. PRECURSOR

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	79200.0000	TF=	1.000000	CDCER=	0.158000
M=	2447.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.500000	Z1=	1.000000	CICER=	0.000400
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			6.756
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.468
#RM =T / M		32.366	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			47.520
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

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TABLE 1.1.9.1.18 CONDUCTORS & INSULATION - P.T. PRECURSOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	60000.0000	TF=	1.000000	CDCER=	0.158000
M=	1720.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			4.147
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.007
#RM =T / M			34.884
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.240
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.19 BATTERIES - P.T. PRECURSOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	8000.00000	TF=	1.000000	CDCER=	0.037000
M=	50.000000	O&M=	0.0	CDEXP=	0.734000
CF=	1.000000	Z1=	1.000000	CICER=	0.028000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.241000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			27.106
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.072
#RM =T / M		160.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			11.501
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.20 THERMAL CONTROL - INSULATION - PRECURSOR

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	23200.0000	TF=	0.048000		CDCER=	0.156000
M=	4.000000	O&M=	0.0		CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000		CICER=	0.101000
PHI=	1.000000	Z2=	60.000000		CIEXP=	0.355000
R=	0.0	Z3=	0.0			
DF=	1.000000	Z4=	60.000000	Z5= 0.0		

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			26.539
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.008
#RM =T / M		5800.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			45.996
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.21 REFERENCE FREQUENCY GENERATOR - PRECURSOR

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	0.500000
M=	1.000000	O&M=	0.0			CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000			CICER=	0.100000
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES SET SUM TO 1.1.9.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.500
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.100
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.100
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.22 DIST. SYSTEM, COAXIAL CABLE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	8613.00000	TF=	1.000000	CDCER=	0.000030
M=	261.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.000060
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	M	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.258
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.016
#RM =T / M		33.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.517
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.23 DIST. SYSTEM DEVICES

INPUT PARAMETERS

T=	100.000000	TF=	1.000000		
M=	2.000000	O&M=	0.0		
CF=	1.000000	Z1=	1.000000		
PHI=	1.000000	Z2=	60.000000		
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

INPUT COEFFICIENTS

CDCER=	0.000225
CDEXP=	1.000000
CICER=	0.005000
CIEXP=	1.000000

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.022
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.010
#RM =T / M		50.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.500
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.24 TRANSMITTER SUBARRAYS - KLYSTRONS DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	282500.000	TF=	1.000000	CDCER=	0.205000
M=	282500.000	O&M=	0.0	CDEXP=	0.507000
CF=	1.250000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KW	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			148.707
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.9.2 EOTV PRECURSOR OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the precursor test activity.

Cost estimates are presented in Table 1.1.9.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.2 COTV PRECURSOR OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.630000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES FLIGHT SUM TO 1.1.9		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.630
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.630
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

1.2 SPACE CONSTRUCTION AND SUPPORT

This element includes all hardware and activities required to assemble, checkout, operate, and maintain the satellite system. Included are space stations, construction facilities, support facilities and equipment, and manpower operations.

The Rockwell reference configuration is used as a baseline for the development of a satellite construction scenario and construction systems/equipment. Precursor operations incident to the establishment of orbital support facilities were identified and the satellite construction sequences and procedures were developed.

The overall scenario leading to establishment of satellite construction support facilities and to satellite construction is shown in Figure 1.2-1. Initial operations entail use of the growth shuttle and the shuttle derived HLLV for transporting men and material to LEO for the precursor phase of the program. Subsequently, during the 30 year satellite construction phase, the sps HLLV will become the primary transportation element for delivering construction mass to LEO and the shuttle HLLV will be used for personnel transfer to LEO.

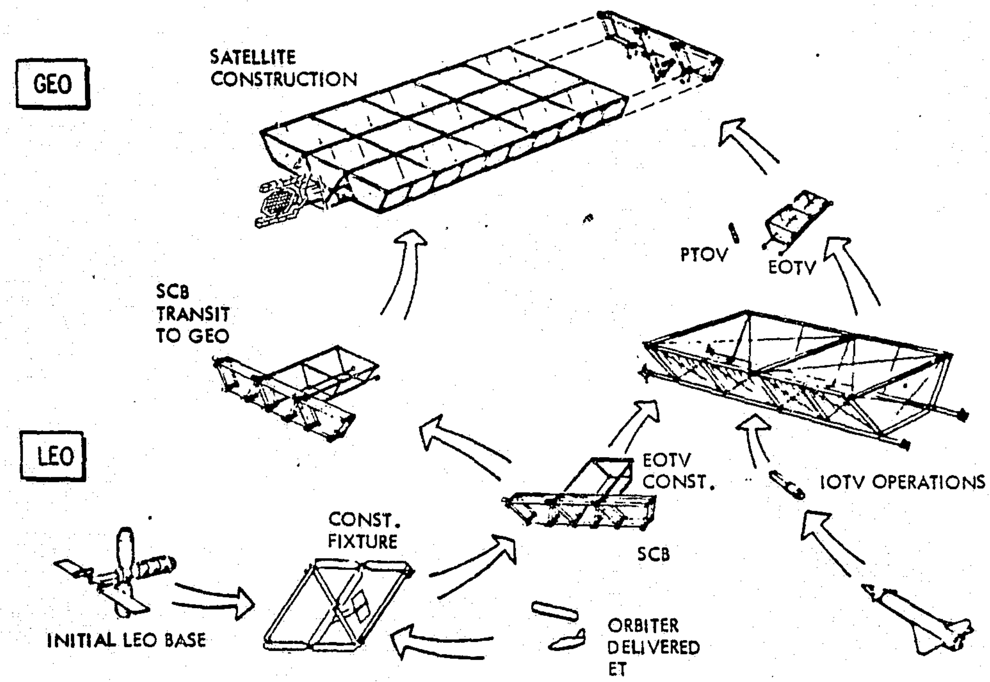


Figure 1.2-1. Overall Satellite Construction Scenario

The initial step in satellite precursor operations is establishment of a LEO base as shown in the lower left of the figure. Crew and power modules are transported to LEO by shuttle derivatives and assembled. When the base is fully operational, shuttle external tanks are delivered and mated to form

construction fixtures for the Satellite Construction Base (SCB) construction. The figure shows a completed SCB. Since the more economical SPS HLLV will not be available during this phase of the program, and since overall plans specify an EOTV test article, it is possible that only the center section of the SCB would be constructed initially. This trough would be used to fabricate the pilot plant EOTV test article with an end-mounted antenna. After proof of concept, the remainder of the SCB would be completed along with sufficient EOTVs to support initial satellite construction operations. The SCB will then be transferred to GEO, using one or more EOTVs for propulsion and attitude control. Upon reaching GEO, satellite construction would commence, with the logistics support as shown at the right of the figure.

The energy conversion segment of the satellite structure is constructed by the integrated SCB in a single pass. Satellite longerons of a length sufficient to connect the triangular frames of the slip ring support structure are fabricated, followed by construction of the slip ring interface structure, and the first satellite structure frame. The SCB then proceeds to fabricate/install the remainder of the satellite structure and solar converter. Construction of the slip rings, and yoke (interface) takes place concurrently using free flying fabrication facilities to support this building process (Figure 1.2-2).

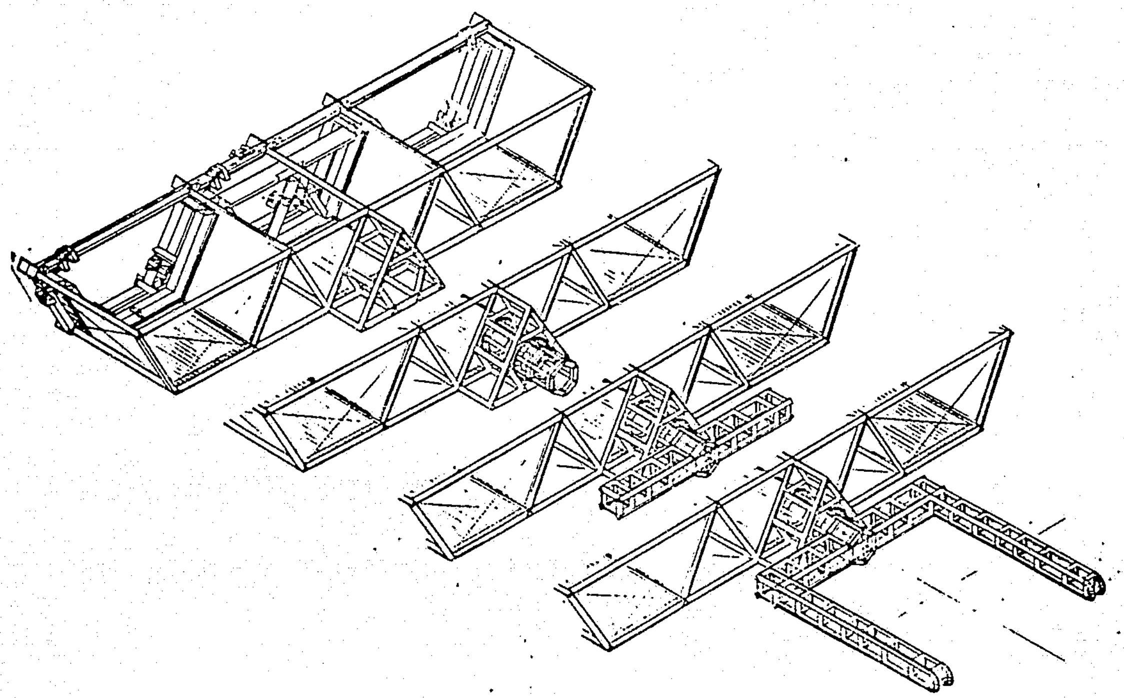


Figure 1.2-2. Antenna Supporting Structure Assembly Sequence

This section addresses the facilities/equipment, and operations required to support SPS work, crew, and operational requirements during the SPS program. Section 1.2.1 deals with the construction facilities; and Section 1.2.2 deals with the work and crew requirements at LEO. Section 1.2.3 covers the requirements in GEO to support operations and maintenance of the satellite.

1.2.1 CONSTRUCTION FACILITIES

This element includes the facilities, equipment, and operations required to assemble and checkout the satellite system. Included are crew life support facilities, the central control facility, fabrication and assembly facilities, cargo depots, and operations.

The satellites are constructed in GEO, each satellite being constructed at its designated longitudinal location. The SCB supports construction of two satellites per year during the program and serves as headquarters for operations and activities necessary to construct such items as the satellite, antenna interface, antenna, and EOTV. The SCB is constructed of composites and consists of the fabrication fixture, construction equipment, and base support facilities.

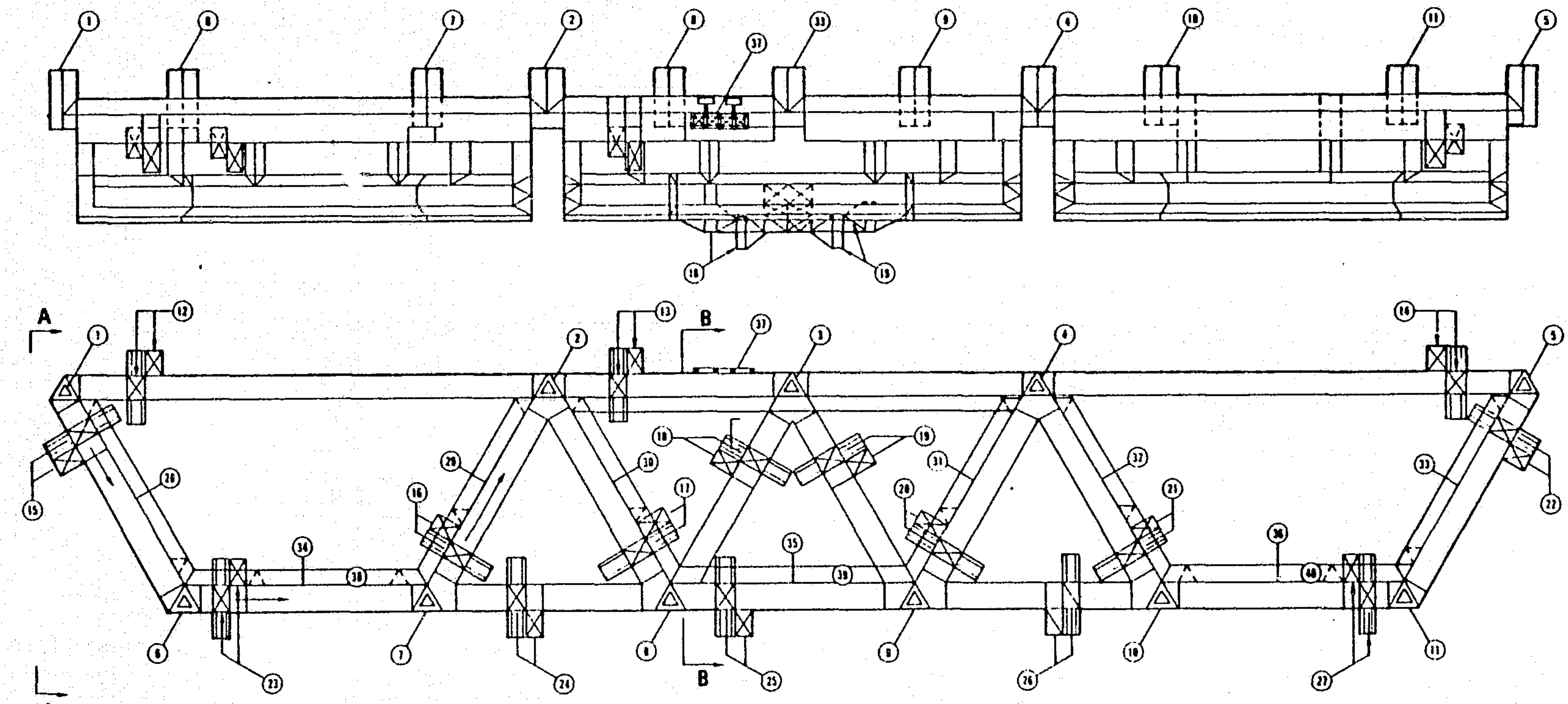
The construction fixture is in the form of three troughs, corresponding to the satellite configuration, which permits simultaneous construction of all troughs. Additional structural members are located in the middle trough and are used as support for the rotary joint/antenna structure. Figure 1.2-3 illustrates the construction base and shows the location of work and crew facilities.

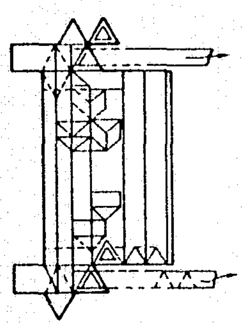
The SCB fabrication fixture assembly and support equipment, and the crew/work modules on the base are itemized in Table 1.2.1. SCB modules used to support the crew/work activities are of various internal configurations to accommodate specific functional requirements. All modules are of the same diameter and most are of the same length, their dimensions and mass being in compliance with space transportation system constraints. The modules are located on the fab fixture along with the assembly and support equipment.

The Airlock Docking Module (ADM) is used to join the other base modules to provide docking accommodations for other elements such as crew transport modules, consumables logistics modules (CLM) and intra-base logistics vehicles, and for transfer of personnel and equipment between different pressure environments. The Crew Habitability Module (CHM) provides stateroom and personal hygiene facilities, and support systems for 24 to 30 crew members. The Base Management Module (BMM) houses the operational communications and control systems for the base. Power Modules (PM) are photovoltaic power systems (collectors, converters, conditioners, and storage) which support all base power requirements. Pressurized Storage Modules (PSM) provide an area for storage and workshop accommodations. Shielding (SHD) is provided in selected modules to protect against solar flare radiation. The Crew Support Module (SM) provides the galley, recreational and medical facilities and support subsystems. Work support, crew, and operational requirements are discussed in the following paragraphs.

1.2.1.1 WORK SUPPORT FACILITIES - SCB

This element includes work facilities and equipment required for satellite assembly and checkout. Included are beam fabricators, manipulators, assembly jigs, installation and deployment equipment, and cargo storage depots. Excluded are the facilities related to crew support.





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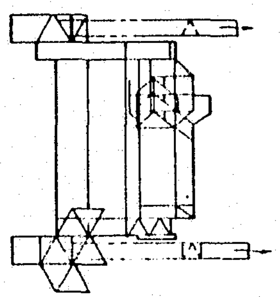

EQUIPMENT & LOCATION DESCRIPTIONS

(1) THRU (11) LONGITUDINAL TRIBEAM FABRICATION PODS

(12) THRU (27) CROSSBEAM FABRICATION PODS

(28) THRU (33) REFLECTOR DISPENSING AREAS

(34) THRU (36) SOLAR BLANKET DISPENSING AREAS

(37) CENTRAL HABITAT-LANDING & WAREHOUSING

(38) THRU (39) AUX HAB/COMPLEX BLANKET FACILITIES

Figure 1.2-3. Satellite Construction Base (SCB)

Satellite Systems Division
Space Systems Group
Rockwell International

Table 1.2.1 Total Space Construction and Support Equipment Requirements

SYSTEM DESCRIPTION	ABBREVIATION	SPACE CONSTRUCTION BASE: WORK SUPPORT FACILITIES	SPACE CONSTRUCTION BASE: CREW SUPPORT FACILITIES
BASE MODULES:			
AIRLOCK DOCKING MODULE	ADM	17	5
CREW HABITABILITY MODULE	CHM		17
CONSUMABLES LOGISTICS MODULE	CLM		9
BASE MANAGEMENT MODULE	BMM	4	
CREW SUPPORT MODULE/EVA	CSM/EVA		
POWER MODULE	PM	4	
PRESSURIZED STORAGE MODULE	PSM	4	
SHIELDING	SHD		8
CREW SUPPORT MODULE	CSM		3
CREW REQUIREMENTS			317 AVG. 504 PEAK
ASSEMBLY AND SUPPORT EQUIPMENT:			
BEAM MACHINES		198	
BEAM MACHINE-CASSETTES		3618	
CABLE ATTACHMENT MACHINES		72	
REMOTE MANIPULATOR		110	
SOLAR BLANKET DISPENSER MACHINE		72	
SOLAR BLANKET CASSETTES		5760	
REFLECTOR DISPENSER MACHINES		6	
REFLECTOR CASSETTES		360	
CABLE/CATENARY DISPENSERS		84	
ANTENNA PANEL INSTALL. EQUIP.		1	
GANTRY/CRANES		12	
CARGO STORAGE DEPOT		4	
SCB FAB FIXTURE		1	

SCB modules used mainly in the support of construction operations include a total of 17 ADMs, 4 BMMs, 4 PMs, and 4 PSMs. The CERs used for these modules were based on Rockwell Space Station studies.

All SPS unique fabrication/orbital construction assembly and support equipment is included in this section (reference Table 1.2.1). Included are the tribeam fabricators, cable attachment machines, solar blanket/concentrator dispensing machines, and antenna panel installation equipment. Each of these requirements were analyzed for equipment usage, replacement factors, O&M, and projected costs based on engineering estimates of design characteristics. The items of assembly and support equipment and base modules remain on the SCB as it transfers from one construction site to another. Cost estimates for these items are presented in Tables 1.2.1.1.1 through 1.2.1.1.17.

1.2.1.2 CREW SUPPORT FACILITIES - SCB

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, central control facilities, recreation facilities, and health facilities of the satellite construction base.

Crew support facilities include 5 ADMs, 17 CHMs, 9 CLMs, 8 SLDs, and 3 CSMs. Detail cost sheets on these components are identified in Tables 1.2.1.2.1 through 1.2.1.2.5.

1.2.1.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the construction facility. It includes both the direct and support personnel and the expendable maintenance supplies for satellite assembly and checkout.

This element has been divided into the subelements of operations (Table 1.2.1.3.1) and consumables (Table 1.2.1.3.2) where an average crew of 317 persons is required to man the SCB over the normal six month fabrication period. A crew rotation is scheduled for every three months. Consumables for the SCB are calculated at 3.6 kg/person/day.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.1 BEAM MACHINE

INPUT PARAMETERS

T=	1.000000	TF=	1.000000		
M=	1.000000	O&M=	0.594000		
CF=	1.000000	Z1=	198.000000		
PHI=	0.920000	Z2=	60.000000		
R=	0.0	Z3=	198.000000		
DF=	1.000000	Z4=	198.000000	Z5 =	0.0

INPUT COEFFICIENTS

CDCER=	2.000000
CDEXP=	1.000000
CICER=	0.700000
CIEXP=	1.000000

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		2.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.700
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		83.150
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.420
CIPS=CTB*Z4/Z2		1.386
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.594

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.2 BEAM MACHINE CASSETTES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.800000
M=	1.000000	O&M=	0.090450	CDEXP=	1.000000
CF=	1.000000	Z1=	1206.00000	CICER=	0.008200
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	3618.00000		
DF=	1.000000	Z4=	1206.00000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.800
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.008
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.315
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3		0.005
CIPS=CTB*Z4/Z2			0.097
CRCI =CTB X R			0.000
CC&M = O&M OR CTB*Z5/Z2/FNYR			0.090

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.3 CABLE ATTACHMENT MACHINE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	4.300000
M=	1.000000	O&M=	0.144000	CDEXP=	1.000000
CF=	1.000000	Z1=	72.000000	CICER=	0.500000
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	72.000000		
DF=	1.000000	Z4=	72.000000	Z5 =	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		4.300
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.500
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		28.228
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.392
CIPS=CTB*Z4/Z2		0.470
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.144

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.4 REMOTE MANIPULATOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	6.880000
M=	1.000000	O&M=	1.925000	CDEXP=	1.000000
CF=	1.000000	Z1=	55.000000	CICER=	1.200000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.033333	Z3=	110.000000		
DF=	1.000000	Z4=	55.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		6.880
CLRM=CICER X (M)XX(CIEXP) X CF X TF		1.200
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		60.390
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3	1.077
CIPS=CTB*Z4/Z2		0.987
CRCI =CTB X R		0.036
CO&M = O&M OR CTB*Z5/Z2/ENYR		1.925

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.5 BLANKET DISPENSER MACHINE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	4.000000
M=	1.000000	O&M=	0.180000	CDEXP=	1.000000
CF=	1.000000	Z1=	72.000000	CICER=	0.400000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	72.000000		
DF=	1.000000	Z4=	72.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		4.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.400
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		26.154
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.363
CIPS=CTB*Z4/Z2		0.436
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.180

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.6 SOLAR BLANKET CASSETTES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.800000
M=	1.000000	O&M=	0.115200	CDEXP=	1.000000
CF=	1.000000	Z1=	1440.00000	CICER=	0.010000
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	5760.00000		
OF=	1.000000	Z4=	2880.00000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.800
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.010
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.076
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.006
CIPS=CTB*Z4/Z2			0.273
CRCI =CTB X R			0.000
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.115

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.7 REFLECTOR DISPENSER MACHINE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	6.000000
M=	1.000000	O&M=	0.048000	CDEXP=	1.000000
CF=	1.000000	Z1=	6.000000	CICER=	0.800000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	6.000000		
DF=	1.000000	Z4=	6.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			6.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.800
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			4.651
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.775
CIPS=CTB*Z4/Z2			0.078
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.048

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.8 REFLECTOR CASSETTES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	1.000000
M=	1.000000	O&M=	0.054000	CDEXP=	1.000000
CF=	1.000000	Z1=	120.000000	CICER=	0.030000
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	360.000000		
DF=	1.000000	Z4=	120.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		1.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.030
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		2.721
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.021
CIPS=CTB*Z4/Z2		0.042
CRCI =CTB X R		0.001
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.054

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.9 CABLE/CATENARY DISPENSER MACHINES

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	2.200000
M=	1.000000	O&M=	0.168000	CDEXP=	1.000000
CF=	1.000000	Z1=	84.000000	CICER=	0.300000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	84.000000		
DF=	1.000000	Z4=	84.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		2.200
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.300
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		22.786
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3	0.271
CIPS=CTB*Z4/Z2		0.380
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.168

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.10 ANTENNA PANEL INS. EQPT.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	600.000000
M=	1.000000	O&M=	6.755000	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	200.000000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	1.000000		
DF=	0.133333	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	80.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	200.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLPM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	200.272
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	200.272
CIPS=CTB*Z4/Z2	3.338
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	6.755

COMMENTS

ROCKWELL SPS CR-2 REFERFNCE CONFIGURATION

TABLE 1.2.1.1.11 GANTRY/CRANES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	17.000000
M=	1.000000	O&M=	0.600000	CDEXP=	1.000000
CF=	1.000000	Z1=	12.000000	CICER=	8.000000
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	12.000000		
DF=	0.800000	Z4=	12.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		13.600
CLRM=CICER X (M)XX(CIEXP) X CF X TF		8.000
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		85.034
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		7.086
CIPS=CTB*Z4/Z2		1.417
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.600

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.12 CARGO STORAGE DEPOTS

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	15.000000
M=	1.000000	O&M=	0.600000	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	2.000000
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	4.000000		
DF=	0.800000	Z4=	4.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		12.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF		2.000
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		7.559
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		1.890
CIPS=CTB*Z4/Z2		0.126
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.600

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.13 FAB FIXTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1648900.00	TF=	1.000000	CDCER=	0.023000
M=	5000.00000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2165.128
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.250
#RM =T / M		329.780	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			82.445
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			82.445
CIPS=CTB*Z4/Z2			1.374
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.14 AIRLOCK DOCKING MODULE (ADM)

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2500.00000	TF=	1.000000	CDCER=	0.0
M=	2500.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	17.000000	CICER=	0.006036
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	17.000000		
DF=	1.000000	Z4=	17.000000	Z5 =	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			15.090
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			242.302
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			14.253
CIPS=CTB*Z4/Z2			4.038
CRCI =CTB X R			0.285
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.1.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.15 BASE MGMT. MODULE (BMM)

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	27000.0000	TF=	1.000000	CDCER=	0.0
M=	27000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	4.000000	CICER=	0.011496
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	4.000000		
DF=	1.000000	Z4=	4.000000	Z5 =	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			310.392
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1213.870
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			303.467
CIPS=CTB*Z4/Z2			20.231
CRCI =CTB X R			6.069
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.1.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.16 POWER MODULE (PM)

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	250.000000	TF=	1.000000	CDCER=	0.0
M=	250.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	4.000000	CICER=	1.100000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	4.000000		
DF=	1.000000	Z4=	4.000000	Z5=	0.0

CALCULATED VALUES	KW	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			275.000
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1075.459
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			268.865
CIPS=CTB*Z4/Z2			17.924
CRCI =CTB X R			5.377
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.1.2 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.17 PRESSURIZED STORAGE MODULE (PSM)

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	15000.0000	TF=	1.000000	CDCER=	0.052914
M=	15000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	0.013734
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.010000	Z3=	4.000000		
DF=	1.000000	Z4=	4.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			793.710
CLRM=CICER X (M)XX(CIEXP) X CF X TF			206.010
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			805.657
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			201.414
CIPS=CTB*Z4/Z2			13.428
CRCI =CTB X R			2.014
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.1 AIRLOCK DOCKING MODULE-ADM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2500.00000	TF=	1.000000	CDCER=	0.012461
M=	2500.00000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	5.000000	CICER=	0.006036
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	5.000000		
DF=	1.000000	Z4=	5.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			31.152
CLRM=CICER X (M)XX(CIEXP) X CF X TF			15.090
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			73.413
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			14.683
CIPS=CTB*Z4/Z2			1.224
CRCI =CTB X R			0.294
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.2 CREW HABITABILITY MODULE-CHM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000			CDCER=	0.0
M=	27000.0000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	17.000000			CICER=	0.003770
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	17.000000				
DF=	1.000000	Z4=	17.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			101.790
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1634.456
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			96.144
CIPS=CTB*Z4/Z2			27.241
CRCI =CTB X R			1.923
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.3 CONSUMABLES LOGISTICS MODULE-CLM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000			CDCER=	0.0
M=	5000.00000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	9.000000			CICER=	0.014000
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	9.000000				
DF=	1.000000	Z4=	9.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			70.000
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			604.675
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			67.186
CIPS=CTB*Z4/Z2			10.078
CRCI =CTB X R			1.344
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS
SEE 1.2.2.2.2 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.4 SHIELDING

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	11000.0000	TF=	1.000000	CDCER=	0.156000
M=	11000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	8.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.010000	Z3=	8.000000		
DF=	0.200000	Z4=	8.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			343.200
CLRM=CICER X (M)XX(CIEXP) X CF X TF			2.748
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			21.160
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2.645
CIPS=CTB*Z4/Z2			0.353
CRCI =CTB X R			0.026
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.5 CREW SUPPORT MODULE-CSM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	15000.0000	TF=	1.000000	CDCER=	0.012432
M=	15000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	3.000000	CICER=	0.005798
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	3.000000		
DF=	1.000000	Z4=	3.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			186.480
CLRM=CICER X (M)XX(CIEXP) X CF X TF			86.970
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			256.587
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			85.529
CIPS=CTB*Z4/Z2			4.276
CRCI =CTB X R			1.711
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.3.1 OPERATIONS, CONSTRUCTION CREW

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	317.000000	TF=	1.000000	CDCER=	0.0
M=	317.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.062400
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	31.000000		
DF=	1.000000	Z4=	30.000000	Z5=	0.0

CALCULATED VALUES	MEN	SUM TO 1.2.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			19.781
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			19.781
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			19.781
CIPS=CTB*Z4/Z2			9.890
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.3.2 ORBITAL OPERATIONS,CONST. PROV.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	410832.000	TF=	1.000000	CDCER=	0.0
M=	410832.000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000022
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	31.000000		
DF=	1.000000	Z4=	30.000000	Z5 =	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			9.038
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.038
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			9.038
CIPS=CTB*Z4/Z2			4.519
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.2.2 LOGISTICS SUPPORT FACILITIES - LEO

This element includes the hardware, software and operations required in LEO to support the construction and operations and maintenance of the satellite system. Included are crew life support facilities, cargo and propellant depots, and vehicle servicing facilities necessary for the receiving and transfer of cargo and personnel distined for a construction base or operational satellite located in GEO.

LEO support operations will require a permanent crew of 24 at the LEO facility. These personnel will provide supervisory activities for transfer of up and down payloads between the HLLV and OTVs. They also perform the scheduled maintenance required by the electric propulsion OTV, such as change-out of ion thruster screens. Included are work and crew support facilities (Table 1.2.2) plus required operations.

Table 1.2.2 LEO Base Modules

SYSTEM DESCRIPTION	ABBREVIATION	WORK SUPPORT FACILITIES	CREW SUPPORT FACILITIES
CREW HABITABILITY MODULE	CHM		1
CONSUMABLES LOGISTICS MODULE	CLM		1
BASE MANAGEMENT MODULE	BMM	1	
CREW SUPPORT MODULE/EVA	CSM/EVA		1
POWER MODULE	PM	1	

1.2.2.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required to provide logistics support in LEO. Included are HLLV and OTV docking stations, payload handling equipment, and cargo and propellant storage depots. Excluded are facilities related to crew support.

A 100 kW solar array power module and the base management module are work support facilities. Cost estimates contained in Tables 1.2.2.1.1 and 1.2.2.1.2 were based on Rockwell Space Station studies.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.1.1 BASE MGMT. MODULE-BMM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000			CDCER=	0.091296
M=	27000.0000	O&M=	0.0			CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000			CICER=	0.011496
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	1.000000				
DF=	1.000000	Z4=	1.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2464.993
CLRM=CICER X (M)XX(CIEXP) X CF X TF			310.392
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			310.814
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			310.814
CIPS=CTB*Z4/Z2			5.180
CRCI =CTB X R			6.216
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 RÉFERENCE CONFIGURATION

TABLE 1.2.2.1.2 POWER MODULE-PM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	250.000000	TF=	1.000000	CDCER=	1.400000
M=	250.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	1.100000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES	KW	SUM TO 1.2.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			350.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			275.000
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			275.373
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			275.373
CIPS=CTB*Z4/Z2			4.590
CRCI =CTB X R			5.507
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.2.2.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities at LEO.

The crew habitability module and crew support module/EVA are the same basic configuration as for those on the SCB. However, the crew support module has an airlock and EVA preparation area. A consumables logistics module is the third element of crew support facilities.

CERs used for crew support facilities were based upon Rockwell Space Station studies. See Tables 1.2.2.2.1, 1.2.2.2.2, and 1.2.2.2.3.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.2.1 CREW HABITABILITY MODULE-CHM

INPUT PARAMETERS

T=	27000.0000	TF=	1.000000		
M=	27000.0000	O&M=	0.0		
CF=	1.000000	Z1=	1.000000		
PHI=	0.980000	Z2=	60.000000		
R=	0.020000	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

INPUT COEFFICIENTS

CDCER=	0.009714
CDEXP=	1.000000
CICER=	0.003770
CIEXP=	1.000000

CALCULATED VALUES	KG	SUM TO 1.2.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			262.278
CLRM=CICER X (M)XX(CIEXP) X CF X TF			101.790
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			101.928
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			101.928
CIPS=CTB*Z4/Z2			1.699
CRCI =CTB X R			2.039
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.2.2 CONSUMABLES LOGISTICS MODULE

INPUT PARAMETERS

T=	5000.00000	TF=	1.000000		
M=	5000.00000	O&M=	0.0		
CF=	1.000000	Z1=	1.000000		
PHI=	0.980000	Z2=	60.000000		
R=	0.020000	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

INPUT COEFFICIENTS

CDCER=	0.053000
CDEXP=	1.000000
CICER=	0.014000
CIEXP=	1.000000

CALCULATED VALUES	KG	SUM TO 1.2.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			265.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			70.000
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.095
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			70.095
CIPS=CTB*Z4/Z2			1.168
CRCI =CTB X R			1.402
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.2.3 CREW SUPPORT MODULE/EVA

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000	CDCER=	0.012432
M=	27000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.005798
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			335.664
CLRM=CICER X (M)XX(CIEXP) X CF X TF			156.546
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			156.759
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			156.759
CIPS=CTB*Z4/Z2			2.613
CRCI =CTB X R			3.135
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.2.2.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the logistics support facility. It includes both the direct and support personnel and the expendable maintenance supplies required for logistics support.

An average of 24 crew members are required at the LEO Base to support orbital operations. Engineering estimates were made of the operations and consumable requirements at LEO. See Tables 1.2.2.3.1 and 1.2.2.3.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.3.1 LEO OPERATIONS CREW

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	24.000000	TF=	1.000000			CDCER=	0.0
M=	24.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.062400
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	31.000000				
DF=	1.000000	Z4=	30.000000	Z5=	0.0		

CALCULATED VALUES	MEN	SUM TO 1.2.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.498
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.498
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.498
CIPS=CTB*Z4/Z2			0.749
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.3.2 LEO CREW PROVISIONS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	31104.0000	TF=	1.000000			CDCER=	0.0
M=	31104.0000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.000022
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	31.000000				
DF=	1.000000	Z4=	30.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.2.3		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF				0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF				0.684
#RM =T / M			1.000	
E =1.0 + LOG(PHI) / LOG(2.0)			1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))				0.684
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3				0.684
CIPS=CTB*Z4/Z2				0.342
CRCI =CTB X R				0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR				0.0

COMMENTS

1.2.3 SATELLITE O&M SUPPORT FACILITIES

This element includes the facilities, equipment, and operations required in GEO to support the operations and maintenance of the satellite system. Included are the on-orbit monitor and control facility and the life support facilities and equipment required to provide confortable safe living quarters for the resident crew members.

A permanent satellite operations and maintenance base is installed on each satellite at a location near the antenna to provide best access to all systems of the satellite. The base has facilities for both the crew and for storage of maintenance material, and installation/repair equipment. Table 1.2.3 identifies the supporting facilities.

Table 1.2.3 Satellite O&M Base

SYSTEM DESCRIPTION	ABBREVIATION	WORK SUPPORT FACILITIES	CREW SUPPORT FACILITIES
AIRLOCK DOCKING MODULE	ADM	3	1
CREW HABITABILITY MODULE	CHM		1
CONSUMABLES LOGISTICS MODULE	CLM		1
BASE MANAGEMENT MODULE	BMM	1	
CREW SUPPORT MODULE/EVA	CSM/EVA		1
PRESSURIZED STORAGE MODULE	PSM	2	

1.2.3.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required for operation and maintenance of the satellite system. Included are satellite monitor and control stations and any centralized repair facilities not included under maintenance.

The ADM is required at four places for the integration of other modules comprising the satellite O&M base. Three of these modules are to be used primarily for work support operations. The satellite BMM incorporates a monitoring and fault isolation capability for the SPS satellite subsystems as well as the controls required for alternate operational modes and functional isolation of selected subsystems for maintenance. The cost estimates of these modules and the PSM are shown in Tables 1.2.3.1.1, 1.2.3.1.2 and 1.2.3.1.3. The CERs are based on Rockwell Space Station studies.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.1.1 AIRLOCK DOCKING MODULE-ADM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	2500.00000	TF=	1.000000			CDCER=	0.0
M=	2500.00000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	3.000000			CICER=	0.006036
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	180.000000				
DF=	1.000000	Z4=	180.000000	Z5 =	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			15.090
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			44.520
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			13.352
CIPS=CTB*Z4/Z2			40.056
CRCI =CTB X R			0.267
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.1.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.1.2 BASE MGMT MODULE-BMM

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	27000.0000	TF=	1.000000	CDCER=	0.0
M=	27000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.011496
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5 =	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			310.392
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			310.814
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			283.323
CIPS=CTB*Z4/Z2			283.322
CRCI =CTB X R			5.666
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.1.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.1.3 PRESSURIZED STORAGE MODULE-PSM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	15000.0000	TF=	1.000000			CDCER=	0.0
M=	15000.0000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	2.000000			CICER=	0.013734
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.010000	Z3=	120.000000				
DF=	1.000000	Z4=	120.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			206.010
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			408.244
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			184.403
CIPS=CTB*Z4/Z2			368.805
CRCI =CTB X R			1.844
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.1.1.17 FOR DDT&E

1.2.3.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities.

The combination crew support and EVA module (CSM/EVA) has the same internal function as for the SCB, but occupies only half of the module. The other half is an integrated multi-crew member EVA preparation area and airlock station.

The ADM, CHM, CLM and CSM/EVA modules are costed in Tables 1.2.3.2.1, 1.2.3.2.2, 1.2.3.2.3, and 1.2.3.2.4. The estimates are based on Rockwell's Space Station studies.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.2.1 AIRLOCK DOCKING MODULE-ADM

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	2500.00000	TF=	1.000000	CDCER=	0.0
M=	2500.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.006036
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			15.090
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			15.111
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			13.774
CIPS=CTB*Z4/Z2			13.774
CRCI =CTB X R			0.275
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.1.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.2.2 CREW HABITABILITY MODULE-CHM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000	CDCER=	0.0
M=	27000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.003770
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			101.790
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			101.928
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			92.913
CIPS=CTB*Z4/Z2			92.913
CRCI =CTB X R			1.858
CC&M = O&M OR CTB*Z5/Z2/FNYR			0.0

COMMENTS
SEE 1.2.2.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.2.3 CONSUMABLES LOGISTICS MODULE-CLM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000	CDCER=	0.0
M=	5000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.014000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			70.000
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.095
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			63.895
CIPS=CTB*Z4/Z2			63.895
CRCI =CTB X R			1.278
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.2.2 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.2.4 CREW SUPPORT MODULE/EVA

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000	CDCER=	0.0
M=	27000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.005798
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			156.546
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			156.759
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			142.894
CIPS=CTB*Z4/Z2			142.894
CRCI =CTB X R			2.858
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.2.3 FOR DDT&E

1.2.3.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the O&M support facility. It includes both the direct and support personnel and the expendable maintenance supplies required in GEO for satellite operations and maintenance.

The satellite operations base crew is manned by 30 persons on a continuous basis throughout the year. This crew and supporting provisions are costed in Tables 1.2.3.3.1 and 1.2.3.3.2 based on engineering estimates.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.3.1 SATELLITE OPERATIONS CREW

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	30.000000	TF=	1.000000	CDCER=	0.0
M=	30.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.062400
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	MEN	SUM TO 1.2.3.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.872
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.872
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.872
CIPS=CTB*Z4/Z2			1.872
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.3.2 SATELLITE CREW PROVISIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	38880.0000	TF=	1.000000	CDCER=	0.0
M=	38880.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000022
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.855
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.855
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.855
CIPS=CTB*Z4/Z2			0.855
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.3 TRANSPORTATION

This element of the costing includes all space transportation required to support the satellite system assembly and operation. Included are transportation requirements supporting the precursor activity, launch to LEO, orbit-to-orbit transfer of all hardware, materials, and personnel, and intra-orbit movement of cargo during the construction and lifetime operation of the satellite system.

The overall scenario for SPS space transportation systems consists of seven major elements -- Space Shuttle derivatives for personnel (PLV) and precursor cargo (STS-HLLV); SPS heavy lift launch vehicle (HLLV); electric orbit transfer vehicle (EOTV); intra-orbit transfer vehicle (IOTV); personnel orbit transfer vehicle (POTV); personnel module (PM); and orbital/ground support facilities. Transportation requirements and concepts for SPS vary as a function of program phase. During the verification planning period (1981 - 1987), the baseline Shuttle is used to conduct sortie missions. Later in the verification program "growth" Shuttle is used to deliver personnel and cargo to LEO. The Shuttle derived HLLV is also employed early in the program for LEO fabrication of the space construction base plus support in building the precursor satellite (EOTV) test model. Figure 1.3-1 illustrates early program systems and identifies the SPS VTO/HL HLLV that will be needed for the fabrication of flight EOTVs and the mass-to-orbit requirements of satellite construction.

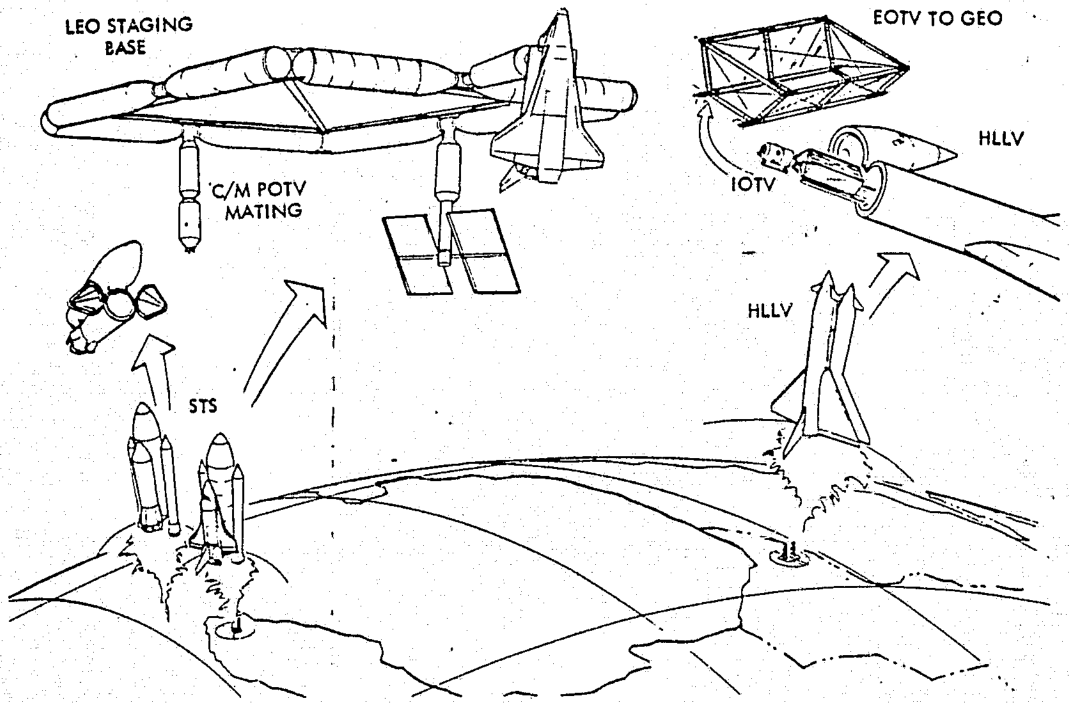

Figure 1.3-1. SPS Transportation System - LEO Operations Operational Program

Geosynchronous orbit is the eventual destination of SPS construction materials/equipment, personnel, and supplies. The crews will be transported from earth to LEO by the growth Shuttle containing the personnel module (PM) where the PM will then be carried to GEO by the POTV. Cargo will be delivered to LEO by the SPS VTO/HL-HLLV configuration, transferred to the EOTV by IOTV's, transported to GEO by the EOTV, and off-loaded by IOTV's. Additional detail on the individual vehicles is presented in later subsections.

Mass-to-orbit requirements for construction, propellant, and operations/maintenance activities were established in accordance with the mission profile and build schedule of two SPS satellites per year with a first unit (TFU) by the end of year 2000. These calculations were based on a round trip vehicle life as shown in Table 1.3-1.

Table 1.3-1. Vehicle Life with Maintenance

VEHICLE	R.T. FLIGHTS PER VEHICLE
STS GROWTH VEHICLE FOR PLV/CARGO	100
SPS-VTO/HL HEAVY LIFT LAUNCH VEHICLE	300
EOTV-CARGO (ELECTRIC) ORBIT TRANSFER VEH.	20
POTV-PERSONNEL ORBIT TRANSFER VEHICLE	100
IOTV-INTRO-ORBIT TRANSFER VEHICLE	200

Table 1.3-2 shows the vehicle fleet and vehicle flight requirements to build the first SPS satellite, LEO construction base, and the EOTV test vehicle. These calculations were based on the mass-to-LEO and GEO for personnel, materials, and supplies identified to each of the transportation modes. Precursor activities can be completed by utilizing (1) the two existing TFU personnel modules (PMs); and (2) an additional PLV over the two needed for the TFU. Two Shuttle launch vehicle sets will be combined with a cargo container/engine module to transport materials to LEO for the precursor activity. TFU vehicle requirements are based on mission timelines, turnaround schedules, and flight profiles.

Table 1.3-3 tabulates the total program transportation requirements and the number of flights per vehicle as needed to construct the satellites and to provide operations and maintenance after IOC. These calculations are the basis for developing overall fleet requirements for a 60-unit SPS program, but do not include the precursor effort identified in Table 1.3-2 nor the additional vehicles needed for attrition/spares or overhaul (replacement capital investment).

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Table 1.3-2. TFU Transportation Requirements

	MASS x 10^6 KG		VEHICLE FLIGHTS					
	LEO	GEO	PLV	HLLV	POTV	EOTV	IOTV LEO	IOTV GEO
SATELLITE CONST. MAINT. & PACKAGING	37.12	37.12	45	163.5	45	6.5	164	164
CREW CONSUMABLES & PKG.	0.98	0.94	-	4.3	-	0.2	4	4
POTV PROPELLANTS & PKG.	2.91	1.46	-	12.8	-	0.3	13	6
EOTV CONST., MAINT. & PKG.	7.20	-	15	31.7	-	-	32	-
EOTV PROPELLANTS & PKG.	4.79	-	-	21.1	-	-	21	-
IOTV PROPELLANTS & PKG.	0.13	0.06	-	0.6	-	-	1	-
							235	174
TOTAL	53.13	39.58	60	234.0	45	7.0	409	
TFU FLEET VEHICLE REQUIREMENTS			2	5	4	6	4	
GROWTH SHUTTLE VEHICLE/OPERATIONS REQUIREMENTS FOR PRECURSOR ACTIVITIES (LEO BASE, SPACE CONSTRUCTION BASE, AND EOTV TEST VEHICLE - EOTV'S)			72 FLIGHTS 1 VEHICLE PERSONNEL (PLV)			129 FLIGHTS 2 VEHICLES CARGO CARRIER/ENGINE MODULE AND LAUNCH VEHICLE		

Table 1.3-3. Total Program Transportation Requirements

	MASS x 10^6 KG		VEHICLE FLIGHTS					
	LEO	GEO	PLV	HLLV	POTV	EOTV	IOTV LEO	IOTV GEO
SATELLITE								
CONSTRUCTION	2197.8	2197.8	1340	9682	1220	425.1	9682	9682
OPERATIONS & MAINTENANCE	1803.0	1803.0	3694	7943	3660	348.7	7943	7943
CREW CONSUMABLES								
CONSTRUCTION	31.5	28.7	-	139	-	5.6	139	126
OPERATIONS & MAINTENANCE	86.8	86.0	-	382	-	16.6	382	379
POTV PROPELLANTS								
CONSTRUCTION	82.7	41.4	-	364	-	8.0	364	182
OPERATIONS & MAINTENANCE	267.8	133.8	-	1180	-	25.9	1180	589
EOTV CONSTRUCTION								
CONSTRUCTION	28.2	24.2	-	124	-	4.7	124	107
OPERATIONS & MAINTENANCE	22.2	19.0	-	98	-	3.7	98	84
EOTV PROPELLANTS								
CONSTRUCTION	340.3	2.0	-	1499	-	0.4	1499	9
OPERATIONS & MAINTENANCE	304.0	-	-	1339	-	-	1339	-
IOTV PROPELLANTS								
CONSTRUCTION	7.2	3.3	-	32	-	0.6	32	15
OPERATIONS & MAINTENANCE	6.6	3.0	-	29	-	0.6	29	13
SUMMARY								
CONSTRUCTION	2687.7	2297.4	1340	11,840	1220	444	11,840	10,121
OPERATIONS & MAINTENANCE	2490.4	2044.8	3694	10,971	3660	396	10,971	9,008
TOTAL	5178.1	4342.2	5034	22,811	4880	840	22,811	19,129
VEHICLE FLEET								
CONSTRUCTION	-	-	14	39	12	22	110	
OPERATIONS & MAINTENANCE	-	-	37	37	37	20	100	
TOTAL	-	-	51	76	49	42	210	

1.3.1 SPS HEAVY LIFT LAUNCH VEHICLE (HLLV)

The SPS HLLV is shown in Figure 1.3-2 and has a payload capability of 227,000 kg with a vertical take-off and horizontal landing feature. The SPS HLLV is used to bring space construction and support equipment payloads, satellite system hardware, OTVs, consumables and crew expendables, and propellants from earth to LEO. This element covers the SPS HLLV vehicles and operations required to support the satellite system assembly and operation during a 30 year life. Ground rules and guidelines applicable to the HLLV are summarized in Table 1.3-4.

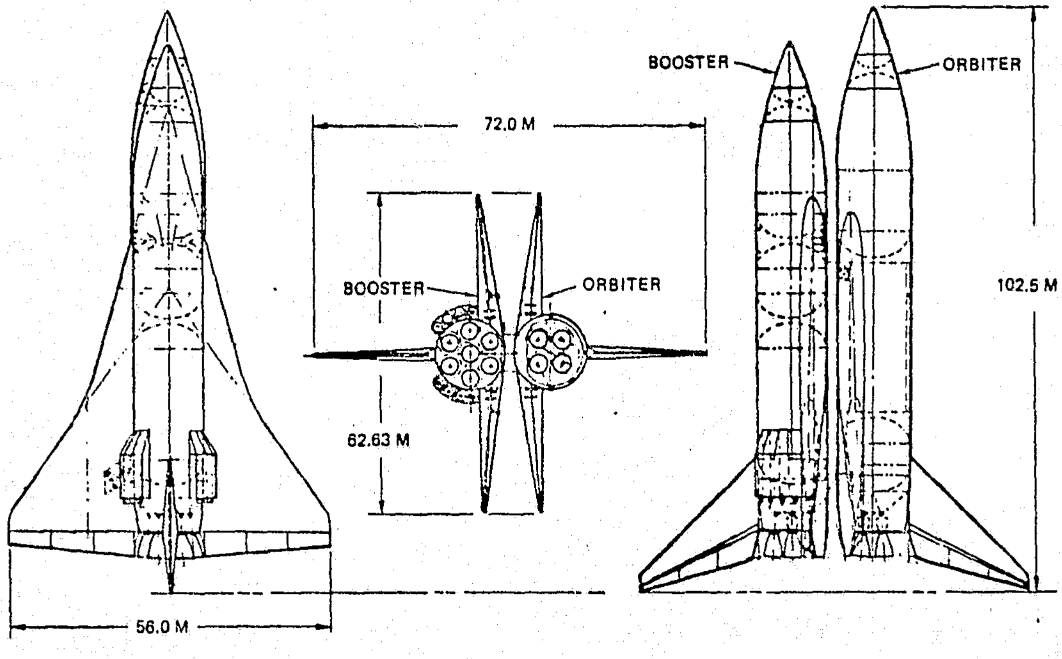

Figure 1.3-2. SPS Transportation System Launch Configuration

Table 1.3-4. HLLV Ground Rules/Assumptions

TWO-STAGE VERTICAL TAKEOFF/HORIZONTAL LANDING (VTO/HL)
FLY BACK CAPABILITY BOTH STAGES - ABES FIRST STAGE ONLY
PARALLEL BURN WITH PROPELLANT CROSSFEED
LOX/RP FIRST STAGE - LOX/LH_2 SECOND STAGE
HI P_c GAS GENERATOR CYCLE ENGINE - FIRST STAGE [I_s (VAC) = 352 SEC.]
HI P_c STAGED COMBUSTION ENGINE - SECOND STAGE [I_s (VAC) = 466 SEC.]
STAGING VELOCITY - HEAT SINK BOOSTER COMPATIBLE
CIRCA 1990 TECHNOLOGY BASE - BAC/MMC WEIGHT REDUCTION DATA
ORBITAL PARAMETERS - 487 KM @ 31.6°
PAYLOAD CAPABILITY - 227×10^3 KG UP/45 KG DOWN
THRUST/WEIGHT - 1.30 LIFTOFF/3.0 MAX
15% WEIGHT GROWTH ALLOWANCE/0.75% ΔV MARGIN

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1.3.1.1 SPS HLLV FLEET

A total of 76 HLLV vehicles are required to handle the mass flow requirements throughout the 60 year SPS program. Thirty-nine vehicles are required for the construction of 60 satellites and 37 vehicles are needed for operation and maintenance during the 30 year satellite lifetime.

Data used in projecting estimates for the HLLV and supporting flight costs were factored from the NASA/JSC contract NAS9-15196. Specific changes were made to consider the reference HLLV design configuration; vehicle complexity factors -- engines, ablative shield, propellant valves, and system/subsystem design; plus the greater mass of the Orbiter/booster as compared with current experience and Rockwell Space Shuttle contract work.

HLLV capital asset replacements, major overhaul requirements, spares provisioning, and system lifetimes were projected as being equivalent to two vehicle replacements for each of the SPS fleet vehicles. These calculations are reflected as an annual cost per satellite over the 30 year period.

The DDT&E cost estimate was developed from a careful evaluation of the NAS9-15196 data base and a comparative factoring of these data as compared with data directly applicable to the Space Shuttle program.

See Table 1.3.1.1 for the SPS HLLV cost computer program tabulation.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.1.1 SPS-HLLV FLEET

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	8600.00000
M=	1.000000	O&M=	0.0			CDEXP=	1.000000
CF=	1.000000	Z1=	5.000000			CICER=	2000.00000
PHI=	0.920000	Z2=	60.000000			CIEXP=	1.000000
R=	0.084440	Z3=	228.000000				
DF=	1.000000	Z4=	39.000000	Z5=	37.000000		

CALCULATED VALUES	SET	SUM TO 1.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			8600.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			2000.000
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			8950.176
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1180.031
CIPS=CTB*Z4/Z2			767.020
CRCI =CTB X R			99.642
CO&M = O&M OR CTB*Z5/Z2/ENYR			24.256

COMMENTS

1.3.1.2 SPS HLLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS program. The HLLV has a lifetime capability of 300 flights.

There are a total of 22.811 round trip flights required to support the 60 year program where approximately 227,000 kg is delivered per flight. These are grouped into a total of 11840 flights for construction and 10,971 flights for operations and maintenance. The TFU requires a total of 234 flights to carry the necessary mass to orbit. On the average of 60 satellites, approximately 197 flights are needed for satellite construction and 6 flights are required for annual operations and maintenance per satellite.

The projected cost per HLLV flight is based on contract data (reference NAS9-15196) that was factored and revised to arrive at a propellant, payload integration, and supporting operational cost by evaluation against such things as propellant costs versus HLLV requirements. See Table 1.3.1.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.1.2 SPS-HLLV OPERATIONS

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	234.000000	CICER=	2.480000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
P=	0.0	Z3=	22811.0000		
DF=	1.000000	Z4=	11840.0000	Z5=	10971.0000

CALCULATED VALUES FLIGHT SUM TO 1.3.1 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	2.480
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	580.320
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	2.480
CIPS=CTB*Z4/Z2	489.387
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	15.116

COMMENTS

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1.3.2 CARGO ORBITAL TRANSFER VEHICLE (COTV)

This element includes the COTV vehicle and operations required to support the satellite system assembly and operation. Included is the LEO-to-GEO transfer of space construction and support equipment, satellite system hardware, spares, and propellants required throughout the satellite lifetime.

The Rockwell cargo orbital transfer vehicle is a high specific impulse configuration that is possible with electric propulsion. The concept is shown in Figure 1.3-3 and has a payload capability of 5.17×10^6 kg (equivalent to 23 HLLV payloads) with a 6 month round trip time per flight.

COTV fleet procurement and operations are detailed in sections 1.3.2.1 and 1.3.2.2, respectively.

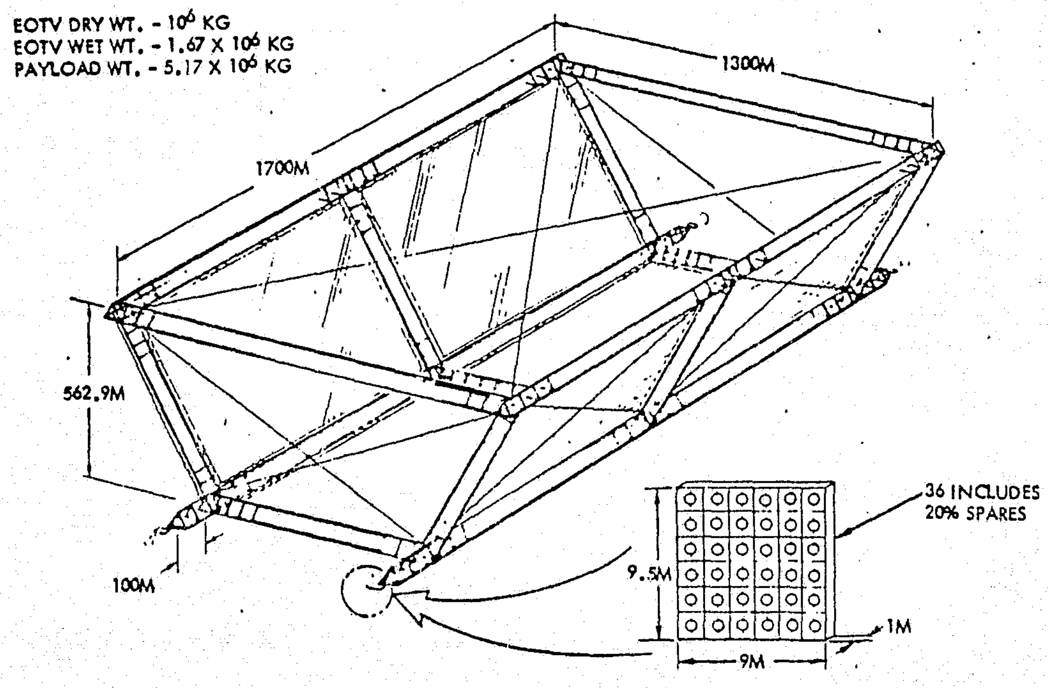

Figure 1.3-3. EOTV Reference Configuration

1.3.2.1 COTV FLEET

This element includes the vehicle fleet procurement required for the SPS.

The electric OTV structural configuration is essentially the same as that employed for the satellite bay. It has a weight of 871,753 kg's. The EOTV weight and payload summary is shown in Table 1.3-5.

Table 1.3-5. EOTV Weight Summary (kg) (GaAlAs)

SOLAR ARRAY		588,196
CELL/STRUCTURE	299,756	
POWER CONDITIONING	288,440	
THRUSTER ARRAY (4)		96,685
THRUSTERS/STRUCTURE	10,979	
CONDUCTORS	4,607	
BEAMS/GIMBALS	2,256	
PROPELLANT TANKS	78,843	
ATTITUDE CONTROL SYSTEM		186,872
POWER SUPPLY (INCL. ENERGY STORAGE)	184,882	
SYSTEM COMPONENTS	274	
PROPELLANT TANKS	1,716	
EOTV INERT WEIGHT		871,753
25% GROWTH		217,938
TOTAL INERT WEIGHT		1,089,691
PROPELLANT WEIGHT		666,660
TRANSFER PROPELLANT	655,219	
ACS PROPELLANT	11,441	
EOTV LOADED WEIGHT		1,756,351
PAYLOAD WEIGHT		5,171,318
LEO DEPARTURE WEIGHT		6,927,669

The thruster array consists of 36 units at four locations for a total of 144 thrusters with a maximum of 64 thrusters operable simultaneously. The total attitude control system and thruster array mass is equal to 283,557 kg's per EOTV.

The EOTV CERs are the same as those used for the satellite costs on the same subsystem elements. The replacement capital investment calculation is based on an attrition factor of 5-6% of each flight vehicle. Table 1.3-6 lists the elements of cost for the EOTV.

Table 1.3-6. EOTV Cost Elements

WBS NO.	DESCRIPTION
1.3.2.1.1	PRIMARY STRUCTURE
1.3.2.1.2	SECONDARY STRUCTURE
1.3.2.1.3	CONCENTRATOR
1.3.2.1.4	SOLAR BLANKET
1.3.2.1.5	SWITCHGEAR AND CONVERTERS
1.3.2.1.6	CONDUCTORS AND INSULATION
1.3.2.1.7	ACS HARDWARE
1.3.2.1.8	INFO MANAGEMENT AND CONTROL

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.1 PRIMARY STRUCTURE

INPUT PARAMETERS					INPUT COEFFICIENTS
T=	30890.0000	TF=	1.000000	CDCER=	0.023000
M=	2059.00000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	6.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.003500	Z3=	44.000000		
DF=	0.020000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.930
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.103
#RM =T / M		15.002	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.267
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.544
CIPS=CTB*Z4/Z2			0.566
CPCI =CTB X R			0.005
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.017

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	14918.0000	TF=	1.000000	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	6.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.003500	Z3=	44.000000		
DF=	0.050000	Z4=	22.000000	Z5 =	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			4.582
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.179
#RM =T / M	2983.600		
E =1.0 + LOG(PHI) / LOG(2.0)	0.971		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2478.750
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			389.820
CIPS=CTB*Z4/Z2			142.934
CRCI =CTB X R			1.364
CC&M = O&M OR CTB*Z5/Z2/ENYR			4.331

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.3 CONCENTRATOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1800000.00	TF=	1.000000	CDCER=	0.027000
M=	450000.000	O&M=	0.0	CDEXP=	0.394000
CF=	1.000000	Z1=	6.000000	CICER=	0.000003
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.950000
R=	0.003500	Z3=	44.000000		
DF=	0.020000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	SQ M	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			1.685
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.704
#RM =T / M		4.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			15.818
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2.494
CIPS=CTB*Z4/Z2			0.914
CRCI =CTB X R			0.009
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.028

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.4 SOLAR BLANKET

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	900000.000	TF=	1.000000	CDCER=	0.161400
M=	18750.0000	O&M=	0.0	CDEXP=	0.394000
CF=	1.000000	Z1=	6.000000	CICER=	0.000067
PHI=	0.990000	Z2=	60.000000	CIEXP=	1.000000
R=	0.003500	Z3=	44.000000		
DF=	0.020000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	SQ M	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.664
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.256
#RM =T / M		48.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.986	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			338.117
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			54.757
CIPS=CTB*Z4/Z2			20.077
CRCI =CTB X R			0.192
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.608

COMMENTS

NASA/ADL NAS 9-15294 MARCH 1978

$67/SQ M

MTLS $33/SQ M & PROCESSING $34/SQ M.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.5 SWITCHGEAR AND CONVERTERS

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	2875.00000	TF=	1.000000	CDCER=	0.158000
M=	719.000000	O&M=	0.0	CDEXP=	0.297000
CF=	1.500000	Z1=	6.000000	CICER=	0.000400
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.001111	Z3=	44.000000		
DF=	0.500000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.054
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.431
#RM =T / M		3.999	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			8.760
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.268
CIPS=CTB*Z4/Z2			0.465
CRCI =CTB X R			0.001
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.014

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.6 CONDUCTORS AND INSULATION

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	357675.000	TF=	1.000000	CDCER=	0.158000
M=	7452.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	6.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.001111	Z3=	44.000000		
DF=	0.020000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.205
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.030
#RM =T / M		47.997	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			8.584
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.431
CIPS=CTB*Z4/Z2			0.525
CRCI =CTB X R			0.002
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.016

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.7 ACS HARDWARE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	283557.000	TF=	0.093800	CDCER=	1.122000
M=	1970.00000	O&M=	0.0	CDEXP=	0.190000
CF=	1.000000	Z1=	6.000000	CICER=	0.057000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.729000
R=	0.003500	Z3=	44.000000		
DF=	0.300000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			9.697
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.348
#RM =T / M		143.938	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			762.015
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			109.634
CIPS=CTB*Z4/Z2			40.199
CRCI =CTB X R			0.384
CO&M = O&M OR CTB*Z5/Z2/ENYR			1.218

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.8 INFO. MGMT. AND CONTROL

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	6.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	$	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M		0.0	
E =1.0 + LOG(PHI) / LOG(2.0)		0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.3.2.2 COTV OPERATIONS

Necessary vehicle operations (user charge per flight including payload integration) is included in this element.

The flight life of the EOTV is estimated at 20 round trips from LEO to GEO. Four hundred forty-four flights are required for the construction of 60 satellites and an additional 396 flights will maintain the operational satellites for the 30 year period. Seven flights are required to build the first satellite.

The calculations used in this cost estimate are presented in Table 1.3.2.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION
TABLE 1.3.2.2 COTV OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	7.000000	CICER=	0.630000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	840.000000		
DF=	1.000000	Z4=	444.000000	Z5=	396.000000

CALCULATED VALUES FLIGHT SUM TO 1.3.2		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.630
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		4.410
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.630
CIPS=CTB*Z4/Z2		4.662
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.139

COMMENTS

1.3.3 PERSONNEL LAUNCH VEHICLE (PLV)

This element includes the space shuttle growth vehicles and operations required to support the satellite system assembly and operation. Included is the launch to LEO and return of all personnel and priority cargo required throughout the satellite construction period and operational lifetime.

In addition to the earth-to-LEO transfer of personnel during satellite construction and operational periods, the space shuttle growth vehicle will 1) accommodate the transfer of personnel and 2) with the cargo/engine module adaptation, will transfer the cargo/material needed for precursor activities dealing with the LEO Base, Space Construction Base, and the initial EOTV-335 mW precursor test article. Shuttle goowth vehicle and flight requirements for the SPS Grogram are identified in Table 1.3.3.

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Table 1.3.3. Shuttle Growth Vehicle and Flight Requirements

VEHICLE/ITEM DESCRIPTION	PRECURSOR PROGRAM	TFU	SATELLITE CONSTRUCTION	SATELLITE O&M	VEHICLE ATTRITION/RCI	TOTAL REQUIREMENTS*	PLV VEHICLE	CARGO VEHICLE
VEHICLE REQUIREMENTS								
SHUTTLE ORBITER (STANDARD VERSION)	(1)	(3)	15	37	26	78	1 EA	
SHUTTLE CARGO CARRIER & MODULE	2				1	3		1 EA
EXTERNAL TANK	(201)	(60)	1541	3694		5235	1 EA	1 EA
LIQUID ROCKET BOOSTER	(6)	(10)	34	74	216	324	2 EA	2 EA
FLIGHT REQUIREMENTS								
PERSONNEL LAUNCH VEHICLE (PLV)	(72)	(60)	1412	3694		5106		
CARGO CARRIER LAUNCH VEH. MODULE	129					129		

* Precursor & TFU requirements included in satellite construction quantity.

The Personnel Launch Vehicle (PLV) is described in section 1.3.3.1 along with the Shuttle derived cargo carrier and engine module required to support the precursor program. PLV operations are described in section 1.3.3.2. The Personnel Module is covered in section 1.3.5.1.

1.3.3.1 PLV FLEET

This element includes the vehicle fleet procurement required to support the SPS program. Included are the vehicles for personnel transfer from earth to LEO and for cargo as needed to support the precursor phase of SPS program development.

The PLV consists of a standard Shuttle Orbiter, an external tank, and two liquid rocket boosters. The cargo vehicle configuration is achieved by replacing the orbiter with a cargo carrier and engine module. The external tank and liquid rocket booster (Figure 1.3.3) are common systems used on the Shuttle derived personnel and cargo vehicles. The integral, SSME-35 powered concept requires four engines with a thrust-to-weight ratio at lift-off of 1.335, which is adequate for both nominal and abort trajectories.

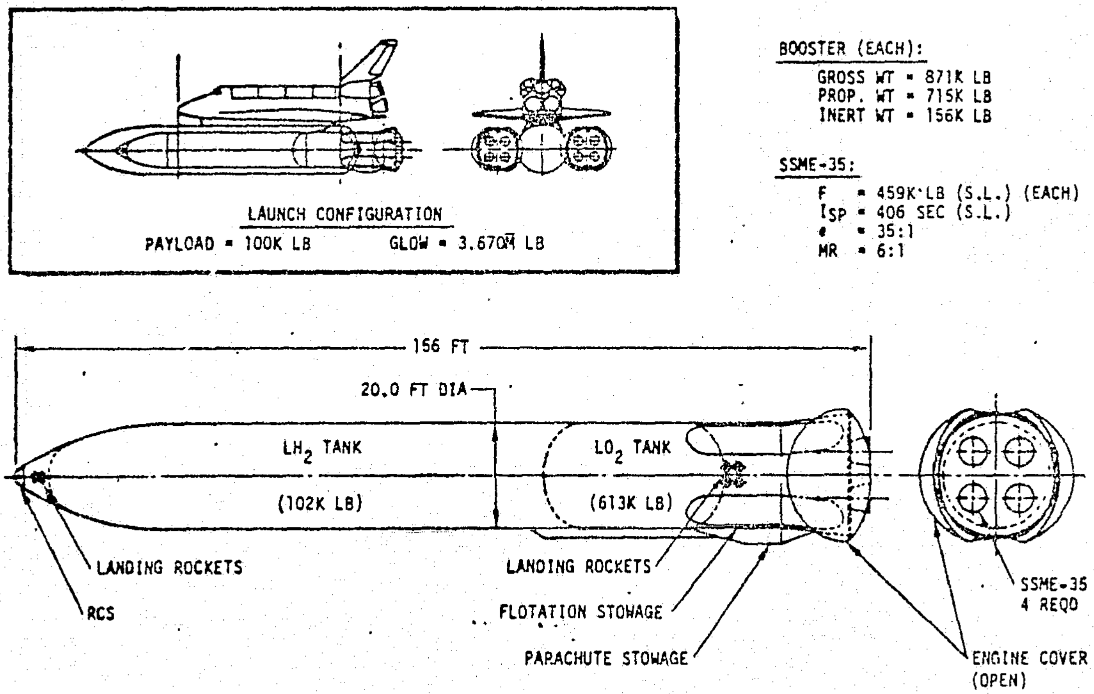


Figure 1.3.3. PLV Configuration

Cost estimates were developed from work produced under the Rockwell Shuttle Growth Study Contract NAS8-32015 of May, 1977. DDT&E, Shuttle Orbiter, external tank, liquid rocket booster, the engine module costs, and projections on operational requirements were identified by comparative evaluation with the Shuttle growth data base. Many different concepts for reducing Shuttle operations costs were examined in the study, but overall cost characteristics clearly reflected the choice of propulsion which lead to the SSME-35 powered LRB as a considered alternative.

Elements of the STS PLV and cargo fleet were individually analyzed on the basis of systems per vehicle, vehicle life, asset rep lacement and operational aspects. A PLV orbiter 30 year replacement factor of 0.5 equivalent vehicles

was used for each orbiter in the fleet. The external tank is an expended item after each flight and the LRBs are to be replaced on the basis of two boosters for each one in the fleet. An attrition/spares factof of 0.5 equivalent vehicles is also used for the cargo/engine module.

DDT&E and system cost estimates are identified in the following tables:

Table No.	Item
1.3.3.1.1	STS-PLV Orbiter
1.3.3.1.2	STS-PLV External Tank
1.3.3.1.3	STS-PLV Liquid Rocket Booster
1.3.3.1.4	STS-Cargo Carrier and Engine Module

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.1.1 STS-PLV ORBITER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	3.000000	CICER=	600.000000
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.014444	Z3=	78.000000		
DF=	1.000000	Z4=	15.000000	Z5=	37.000000

CALCULATED VALUES SET SUM TO 1.3.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	600.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	1682.531
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	401.360
CIPS=CTB*Z4/Z2	100.340
CRCI =CTB X R	5.797
CO&M = O&M OR CTB*Z5/Z2/ENYR	8.250

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.1.2 STS-PLV EXTERNAL TANK

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	0.0
M=	1.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	261.000000			CICER=	4.000000
PHI=	0.920000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	5235.00000				
DF=	1.000000	Z4=	1541.00000	Z5=	3694.00000		

CALCULATED VALUES	SET	SUM TO 1.3.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			4.000
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			606.205
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.623
CIPS=CTB*Z4/Z2			41.6[illegible]9
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			3.330

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.1.3 STS-PLV LIQ. ROCKET BOOSTER

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	1304.00000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	5.000000	CICER=	195.300003
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.060000	Z3=	162.000000		
DF=	1.000000	Z4=	17.000000	Z5=	37.000000

CALCULATED VALUES SET SUM TO 1.3.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	1304.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	195.300
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	873.985
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	119.967
CIPS=CTB*Z4/Z2	33.991
CRCI =CTB X R	7.198
CO&M = O&M OR CTB*Z5/Z2/ENYR	2.466

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.1.4 STS CARGO CARRIER AND EM

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	245.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	3.000000	CICER=	265.800049
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	3.000000		
DF=	1.000000	Z4=	3.000000	Z5=	0.0

CALCULATED VALUES $ SUM TO 1.3.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	245.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	265.800
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	745.362
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	248.454
CIPS=CTB*Z4/Z2	12.423
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1.3.3.2 PLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS program.

A total of 5,235 flights are required of the Shuttle derived personnel and cargo vehicle -- 1,412 for construction, 3,694 for operations, and 129 for the precursor program. The 1,412 PLV flights for construction include 72 for the precursor effort and 60 for the TFU satellite.

Cost estimates per flight were projected after an engineering analysis of the operational costs and vehicle elements identified in the Rockwell Shuttle Growth Study (NAS8-32015). Tables 1.3.3.2.1 and 1.3.3.2.2 cover operational cost estimates.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.2.1 PLV OPERATIONS

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	132.000000	CICER=	9.200000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	5106.00000		
DF=	1.000000	Z4=	1412.00000	Z5=	3694.00000

CALCULATED VALUES FLIGHT SUM TO 1.3.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	9.200
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	1214.400
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	9.200
CIPS=CTB*Z4/Z2	216.507
CRCI =CTB X R	0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR	18.880

COMMENTS

B-225

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.2.2 STS HLLV CARGO OPERATIONS

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	129.000000	CICER=	8.750000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	129.000000		
DF=	1.000000	Z4=	129.000000	Z5=	0.0

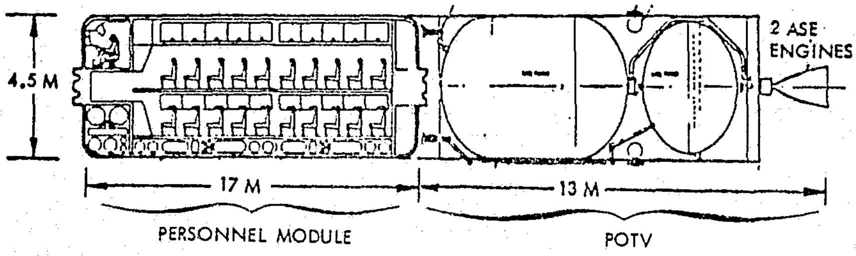
CALCULATED VALUES $	SUM TO 1.3.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		8.750
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		1128.750
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		8.750
CIPS=CTB*Z4/Z2		18.813
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

1.3.4 PERSONNEL ORBITAL TRANSFER VEHICLE (POTV)

This element includes the POTV vehicles and operations required to support the satellite system assembly and operation. Included is the LEO-to-GEO and return of all personnel and priority cargo required throughout the satellite construction and operational periods.

All of the POTV options evaluated utilize a single stage propulsive element that is fueled in LEO and refueled in GEO for the return flight. The reference configuration is illustrated in Figure 1.3.4 where the POTV (a propulsive stage) is capable of transporting a 60-man personnel module (PM) of 18,000 kg. The vehicle is costed in section 1.3.4.1 and POTV operations are covered in section 1.3.4.2.



• 60 MAN CREW MODULE	18,000 KG
• SINGLE STAGE OTV (GEO REFUELING)	36,000 KG
• BOTH ELEMENTS CAPABLE OF GROWTH STS LAUNCH	

Figure 1.3.4. POTV Configuration

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1.3.4.1 POTV FLEET

The vehicle fleet procurement required to support the SPS program is included in this element. The POTV is a single stage OTV of 36,000 kg with refueling at GEO for the return to LEO. Propellants are carried from LEO to GEO by the EOTV. The SPS HLLV carries the construction, crew expendables, and POTV propellants to LEO. The Shuttle Orbiter carries the crew in a personnel module (PM) to LEO for transfer to the POTV.

The single stage OTV configuration selected is a scaled version of those concepts presented in the BAC FSTSA NAS9-24323 contract and engineering analyses presented in Exhibits A/B of the Rockwell contract NAS8-32475. DDT&E estimates considered fewer engines, a significant difference in mass, and the degree of development required for the engines. Engineering analyses of available vehicle estimates projected a POTV cost based on the design and complexity of the vehicle.

POTV cost estimates are presented in Table 1.3.4.1 for a total fleet of 196 vehicles with: 1) 12 for personnel involved in satellite construction, 2) 37 for SPS operational activities, and 3) an attrition factor of 3 equivalent vehicles to keep the fleet fully operational.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.4.1 POTV-FLEET

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	350.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	15.000000
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.081667	Z3=	196.000000		
DF=	1.000000	Z4=	12.000000	Z5 =	37.000000

CALCULATED VALUES SET SUM TO 1.3.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	350.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	15.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	54.764
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	9.010
CIPS=CTB*Z4/Z2	1.802
CRCI =CTB X R	0.736
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.185

COMMENTS

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1.3.4.2 POTV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS program with required personnel.

The primary operational cost of the POTV is the cost of fuel. A total of 4,880 flights were costed on this basis where 1,220 flights were for satellite construction; 3,660 for operations and maintenance; and 45 of the 1,220 needed to support TFU activities. Table 1.3.4.2 presents the results of this analysis.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.4.2 POTV-OPERATIONS

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000		CDCER=	0.0
M=	1.000000	O&M=	0.0		CDEXP=	0.0
CF=	1.000000	Z1=	45.000000		CICER=	0.033742
PHI=	1.000000	Z2=	60.000000		CIEXP=	1.000000
R=	0.0	Z3=	4880.00000			
DF=	1.000000	Z4=	1220.00000	Z5=	3660.00000	

CALCULATED VALUES	$	SUM TO 1.3.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.034
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.518
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.034
CIPS=CTB*Z4/Z2			0.686
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.069

COMMENTS

1.3.5 PERSONNEL MODULE (PM)

This element includes the PM units and operations required to support the satellite system assembly and operation. Included in the earth-to-LEO-to-GEO and return transfer of all personnel and critical hardware items required throughout the satellite construction and operational periods. The PM provides a crew habitat during the orbit-to-orbit transfers of personnel as well as during the trip from earth. An illustration of the PM was shown in Figure 1.3.4. It has a 60-man capacity and is approximately 17 m long by 4.5 m in diameter. The Shuttle is used for the earth-to-LEO transfer and the POTV handles the round trip movement from LEO-GEO-LEO.

1.3.5.1 PM FLEET

Procurement of the PM as required to support the SPS program is covered in this element. The PM is operated by a pilot and co-pilot and contains the major systems of life support, communication, seating, and support facilities. A total of 4 PMs are needed to support the program and 2 equivalent PMs are considered sufficient to provide spares and major overhaul components during the program. Four vehicles will be required to build the satellite TFU and early program supporting elements such as the LEO Base and SCB.

Engineering cost projections were based on Rockwell company-funded studies of 1976 where DDT&E, a pair of 68 passenger modules, and the orbiter modification kits were costed from internal design specifications. PM fleet procurement costs are presented in Table 1.3.5.1.

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.5.1 PM FLEET

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	118.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	54.399994
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.004444	Z3=	12.000000		
DF=	1.000000	Z4=	1.000000	Z5=	3.000000

CALCULATED VALUES SET SUM TO 1.3.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	118.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	54.400
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	198.610
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	44.737
CIPS=CTB*Z4/Z2	0.746
CRCI =CTB X R	0.199
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.075

COMMENTS

1.3.5.2 PM OPERATIONS

This element includes the necessary operations (user charge per flight including payload integration) required to support the SPS program.

A PM crew (pilot and co-pilot) will command the module during earth-to-LEO trips on the Shuttle and complete the procedures of leaving the Shuttle and making the POTV hook-up for transfer to GEO. The crew will monitor passenger off-loading/transfer to and from the LEO Base, SCB, or satellite O&M Base. Two man-days are calculated per trip which includes a rest period at GEO and a day off after the trip. An average of 4,993 round trip flights are projected from earth to GEO and back. A total of 132 flights are needed for the precursor and TFU programs. The engineering estimates of PM operations are presented in Figure 1.3.5.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.5.2 PM OPERATIONS

INPUT PARAMETERS

T=	1.000000	TF=	1.000000		
M=	1.000000	O&M=	0.0		
CF=	1.000000	Z1=	132.000000		
PHI=	1.000000	Z2=	60.000000		
R=	0.0	Z3=	4993.00000		
DF=	1.000000	Z4=	1316.00000	Z5=	3677.00000

INPUT COEFFICIENTS

CDCER=	0.0
CDEXP=	0.0
CICER=	0.025000
CIEXP=	1.000000

CALCULATED VALUES FLIGHT SUM TO 1.3.5 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.025
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	3.300
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.025
CIPS=CTB*Z4/Z2	0.548
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.051

COMMENTS

1.3.6 INTRA-ORBITAL TRANSFER VEHICLE (IOTV)

This element includes the IOTV vehicles and operations required to support the satellite system assembly and operation. Included is the intra-orbit transfer of cargo between the HLLV, EOTV, construction facility, logistics support facility, and operational satellites.

1.3.6.1 IOTV FLEET

This element includes the necessary vehicle fleet procurement required to support the SPS program. The IOTV has been synthesized in terms of application and concept only. IOTV elements considered here are powered by a chemical (LOX/LH_2) propulsion system. At least three distinct applications have been identified; (1) the need to transfer cargo from the HLLV to the EOTV in LEO and from the EOTV to the SPS construction base in GEO; (2) the need to move materials about the SPS construction base; and (3) the probable need to move men or materials between operational SPSs. Clearly the POTV, used for transfer of personnel from LEO to GEO and return, is too large to satisfy all intra-orbit requirements. A "free-flyer" teleoperator concept would appear to be a logical solution to the problem. A propulsive element was synthesized to satisfy the cargo transfer application from HLLV-EOTV-SPS base in order to quantify potential on-orbit propellant requirements. Pertinent IOTV parameters are summarized in Table 1.3.6.

Table 1.3.6. IOTV Design Parameters

SUBSYSTEM	WEIGHT (kg)
ENGINE (1 ASE)	245
PROPELLANT TANKS	15
STRUCTURE AND LINES	15
DOCKING RING	100
ATTITUDE CONTROL	50
OTHER	100
SUBTOTAL	525
GROWTH (10%)	53
TOTAL INERT	578
PROPELLANT	300
TOTAL LOADED	878

A total of 840 IOTVs are needed to maintain intra-orbit cargo/operations flow during the program. One hundred ten vehicles will accomplish the construction phase and 100 vehicles are needed for satellite O&M. An attrition/spares fleet of equivalent vehicles was projected on the ratio of 3 units for each of the operational vehicles.

Cost estimates for the IOTV are engineering assessments based on POTV designs and similarities such as those of the common advanced space engine (ASE). Table 1.3.6.1 displays the applicable cost data.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.6.1 IOTV FLEET

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	100.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	1.500000
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.350000	Z3=	840.000000		
DF=	1.000000	Z4=	110.000000	Z5=	100.000000

CALCULATED VALUES SET SUM TO 1.3.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	100.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	1.500
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	5.476
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.758
CIPS=CTB*Z4/Z2	1.389
CRCI =CTB X R	0.265
CC&M = O&M OR CTB*Z5/Z2/ENYR	0.042

COMMENTS

1.3.6.2 IOTV OPERATIONS

This element includes the necessary vehicle operations and propellant costs required to support the SPS program. It includes the on-orbit operational cost of transferring cargo at LEO and GEO.

A total of 41,940 IOTV flights are planned for LEO and GEO construction and operations/maintenance requirements of the program. The 22,811 flights needed for construction and the 19,979 for operations and maintenance are considered as equal missions for the purpose of costing. The propellant requirements were averaged and calculated at 1977 dollars of \$0.07/kg for LO_2 and \$3.27/kg for LH_2. A 40% mark-up was added per flight for other operational and maintenance charges. See Table 1.3.6.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.6.2 IOTV OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	408.000000	CICER=	0.000222
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	41940.0000		
DF=	1.000000	Z4=	21961.0000	Z5=	19979.0000

CALCULATED VALUES FLIGHT SUM TO 1.3.6 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.000
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.091
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.000
CIPS=CTB*Z4/Z2		0.081
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.002

COMMENTS

1.3.7 GROUND SUPPORT FACILITIES

This element includes all land, buildings, roads, shops, etc., required to support the cargo handling, launching, recovering, refurbishment, and operations of the space transportation system.

1.3.7.1 LAUNCH FACILITIES

This element includes the design and construction of the actual launch facility and its associated equipment. Included are land, buildings, and equipment required to support the various crews. It also includes the required control centers and administrative facilities.

1.3.7.2 RECOVERY FACILITIES

This element covers the design, construction, and equipping of the actual recovery facilities.

1.3.7.3 FUEL FACILITIES

This element includes fuel production facilities, storage and handling facilities, transportation, and delivery and safety facilities for both the fuel and the oxidizer. Also included are the facilities for fuels used in the various orbital transfer facilities.

1.3.7.4 LOGISTICS SUPPORT

This element includes the land, buildings, and handling equipment for the receiving, inspection, and storage and packaging of all payloads to be launched except for fuels and oxidizers.

1.3.7.5 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground support facilities. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground support facilities operation and maintenance.

A cost estimate for ground support facilities is projected in Table 1.3.7 based on the Boeing final report, NAS9-14710, dated September 1977, Volume 4, Cost Estimates. It is judged that there is little difference in the cost of facilities in this report as compared with those projected for the transportation and operations requirements of this study.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.7 GROUND SUPPORT FACILITIES

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	1720.00000
M=	1.000000	O&M=	1.775000	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	3195.00000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.001111	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES SUM TO 1.3 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	1720.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	3195.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	3195.000
CT8 =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	3195.000
CIPS=CT8*Z4/Z2	53.250
CRCI =CT8 X R	3.550
CO&M = O&M OR CT8*Z5/Z2/ENYR	1.775

COMMENTS

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1.4 GROUND RECEIVING STATION

The ground receiving station (GRS) is designed to accept power from a single satellite and to provide a nominal 5 GW of power to the utility interface. As shown in Figure 1.4-1, a typical receiving station would be located at 34° N latitude with rectenna panels covering an elliptical area of 13 km in the north-south direction and 10 km in the east-west direction. This area is surrounded by another elliptical segment to house the power conversion equipment and to provide for the operational facilities of the receiving station. A summary of point design characteristics are presented in Table 1.4-1.

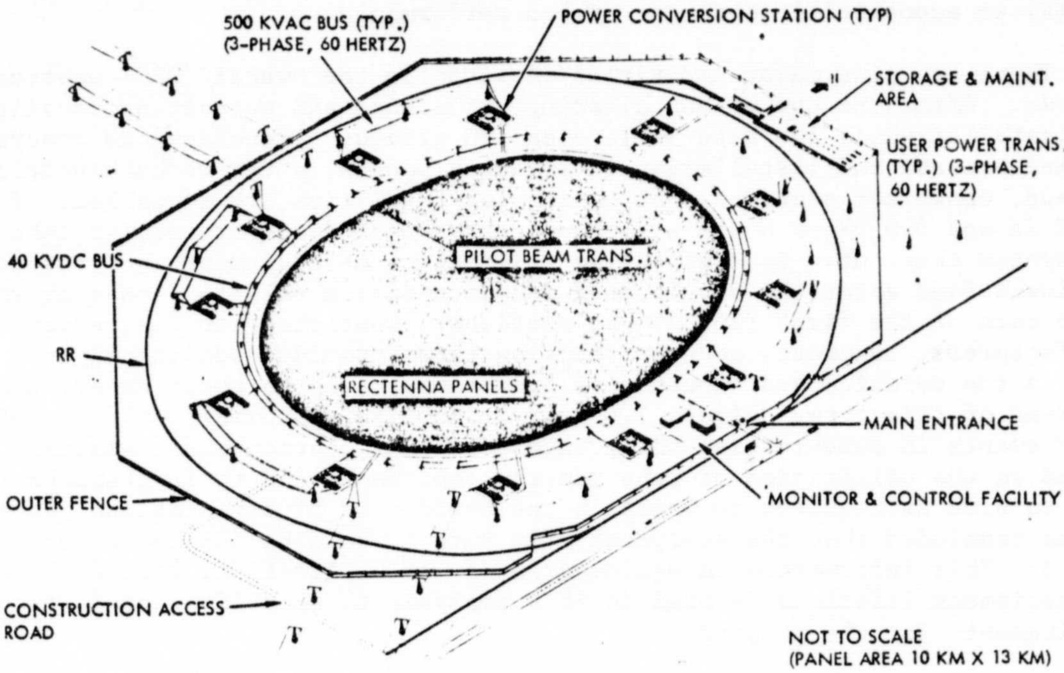

Figure 1.4-1. Operational Ground Receiving Facility (Rectenna) - Typical

Table 1.4-1. System Point Design Characteristics

SIZE (km)	10×13
TOTAL GROUND AREA $(km)^2$	102.1
TOTAL PANEL AREA $(km)^2$	79.53
AREA PER PANEL (9.33×14.69 m)	137.0
NUMBER OF PANELS	580,500
NUMBER OF DIODES	330×10^6
RECTENNA EFFICIENCY (%)	89
VOLTAGE OUTPUT PER STRING (kV dc)	40+
VOLTAGE OUTPUT TO UTILITY (kV ac)	500
POWER OUTPUT (GW) AT UTILITY INTER-TIE	4.61*
*BASED UPON 5.53 GW INCIDENT RADIATION	

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This ground based element of the SPS is comprised of the land, facilities, equipment, and hardware/software systems to receive the radiated microwave power beam and to provide the power at the required voltage and type of current for entry into the national power grid. It also includes the equipment, facilities, and hardware/software necessary to provide operational control over the satellite; and a reliable means of monitoring and controlling ground based systems and equipment.

Major objectives of the SPS ground system design are: (1) to provide low maintenance subsystems and equipment capable of handling the designed power levels; (2) to assure that the overall station will provide dependable service for at least 30 years; (3) to minimize the size of operational crews and costs; and (4) to economically optimize system performance.

There are nine major activities involved in the overall GRS construction process. After the survey and clearing, utilities and supporting facilities are installed while the site is leveled and graded. Trenching and concrete pouring precede the installation of rectenna panels, after which electrical hook-up, converter stations, and monitoring facilities are installed. The 40 kV dc and 500 kV ac buses are then interconnected and procedures take place for system checkout. Cost effective utilization of equipment and personnel was identified after the development and integration of detail phasing schedules on each of the first four ground stations. Contacts with A&E, equipment manufacturers, concrete, and construction firms provided additional information on the duration and sequence of operations based on their experience with programs of this type. Figure 1.4-2 is an integrated summary schedule of major events in constructing the ground receiving station where emphasis is placed on the utilization of construction equipments and their transfer from site to site as required to maintain the build rate of two stations per year. It was concluded that the equipment from Site 1 would be available for use on Site 3. This information on equipment/manpower utilization, site sequencing, and equipment lifetimes is used in this analysis to establish total resource requirements for the program.

The ground receiving station was divided into several main elements for the purpose of associating cost and programmatic definitions. These elements include (1) site and facilities, (2) rectenna support structure, (3) power collection, (4) control, (5) grid interface, and (6) operations. SPS design definitions and specification requirements were analyzed to provide realistic cost estimates and resource definitions for each element as explained in the following sections.

Internal resources, cost estimating relationships, and prior cost analyses were supplemented by: 1) direct contact with business, industry, and institutional organizations, and 2) a literature search of various publications to obtain realistic cost estimates and operational definitions directly applicable to the unique requirements of the GRS. A list of principal organizations and literature sources are presented in Table 1.4-2.

A summary of the costs associated with the GRS is presented in Table 1.4-3. The detail supporting these costs is presented in the subsequent pages of this section.

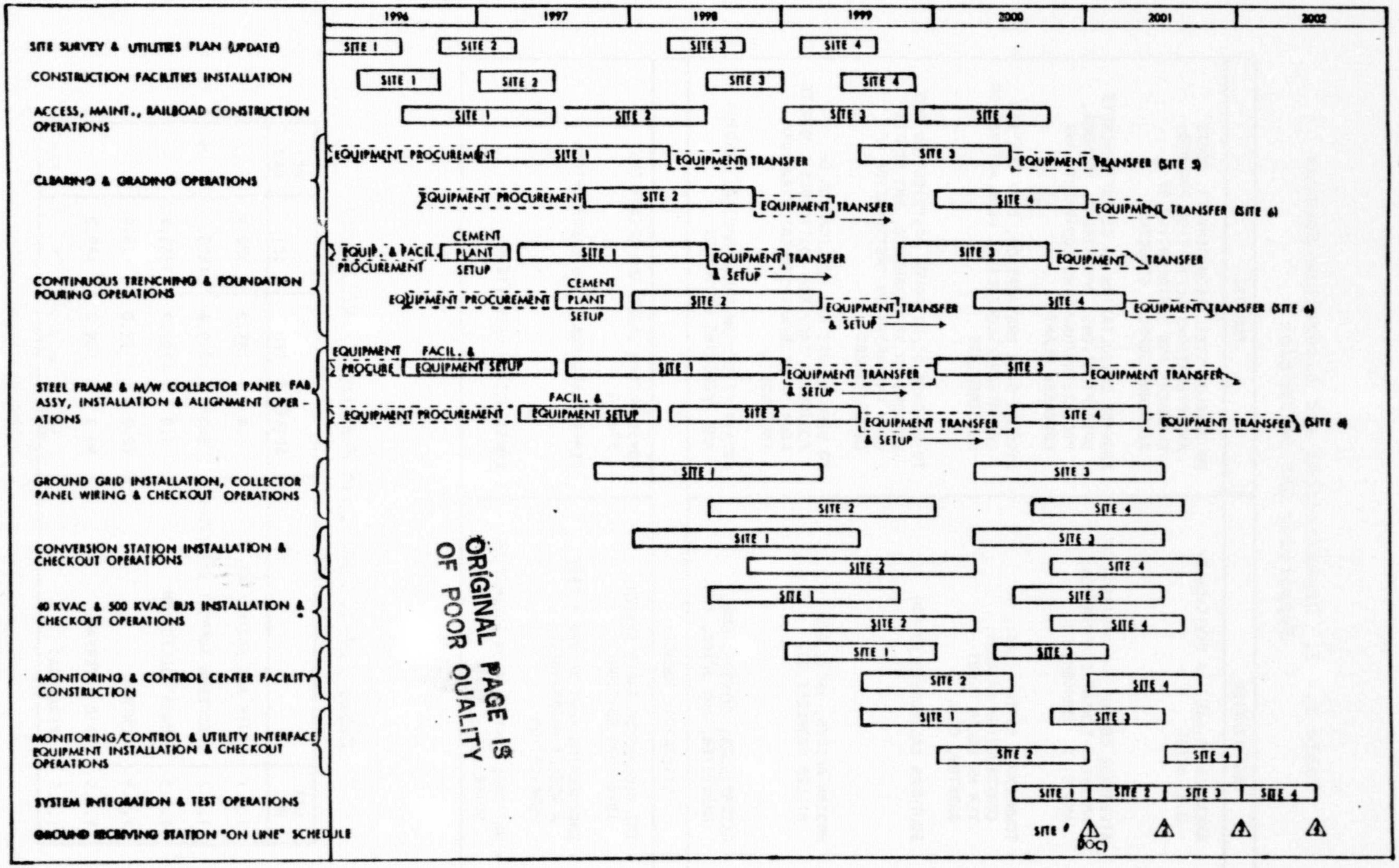

Figure 1.4-2. Rectenna Construction Sequence Summary Schedule

Table 1.4-2. Organizations and Literature Sources Supporting GRS Definition

ORGANIZATION	PURPOSE
• AMERICAN BRIDGE - A DIVISION OF U.S. STEEL	TO DEVELOP STEEL REQUIREMENTS, COSTS AND OPERATIONS DEFINITION FOR PROCUREMENT AND INSTALLATION OF RECTENNA SUPPORT STRUCTURE
• RIVERSIDE CEMENT - A DIVISION OF AMERICAN CEMENT CORPORATION; AND C. S. JOHNSON, CO.	PROVIDE CONSULTATION ON CEMENT/CONCRETE SPECIFICATIONS, OPERATIONAL METHODS, PROCESSING/HANDLING EQUIPMENT, AND CONCRETE PLANT
• TOWNSEND & BOTTUM, INC., CONSTRUCTION MANAGER, TEN MW SOLAR PLANT - BARSTOW, CA.	DISCUSS SITE PREPARATION, CONSTRUCTION OPERATIONS/SEQUENCING, PLUS ACTIVATION REQUIREMENTS
• SOUTHERN CALIFORNIA EDISON	TO DISCUSS DC/AC POWER DISTRIBUTION AND CONVERSION REQUIREMENTS, AND OBTAIN COST ESTIMATES ON INSTALLATION OF LINES/TOWERS
• MODERN ALLOYS, INC.; AND MILLER FORMLESS CO.	TO DISCUSS USE AND APPLICATION OF EQUIPMENT/CREW FOR CONTINUOUS CONCRETE POUR OF RECTENNA SUPPORT STRUCTURE FOOTINGS
• CATERPILLAR; INTERNATIONAL HARVESTER; AND JETCO, INC.	OBTAIN PRICES ON EARTH MOVING, GRADING AND TRENCHING EQUIPMENT
LITERATURE SOURCES	
• THE RICHARDSON RAPID SYSTEM 1978-1979 EDITION	CONSTRUCTION LABOR AND OPERATIONS PRICES
• ENGINEERING NEWS RECORD - 1977 A WEEKLY McGRAW-HILL PUBLICATION	CEMENT, AGGREGATE AND LABOR PRICES
• NATIONAL CONSTRUCTION ESTIMATING GUIDE (NCE)	CONSTRUCTION OPERATIONS

Table 1.4-3. GRS Cost Summary ($ Millions)

WBS NO.		DDT&E	TFU	ICI	RCI/ O&M
1.4.1	SITE AND FACILITIES	1.0	195.2	188.9	.2
1.4.2	RECTENNA SUPPORT STRUCTURE	2.0	1849.6	1828.	.5
1.4.3	POWER COLLECTION	3.0	1353.2	1353.2	-
1.4.4	CONTROL	10.0	75.0	75.0	-
1.4.5	GRID INTERFACE	99.7	145.7	145.7	-
1.4.6	OPERATIONS	-	-	-	77.9

1.4.1 SITE AND FACILITIES

The ground receiving station is located on a site of 35,000 acres where over 25,000 acres of a central ellipse, or 72% of the total acreage, is used for rectenna panels. The area surrounding the inner ellipse is allocated for maintenance/control facilities, access roads, converter stations, and the rows of towers that support the 40 kW dc and 500 kV ac cables. The GRS perimeter is fenced for security reasons.

The sequence of construction operations begins with site identification, environmental impact studies, zoning/permits, surveys, utility/road installation, and supporting facilities. After reference coordinates are established, the site is cleared, leveled, and followed with precise grading for panel foundations, fabrication facilities, installation and GRS site completion. This includes concrete mixing plants, rectenna panel fabrication factories, crew accommodations, warehousing, and support facilities as shown in Figure 1.4-3. The GRS DDT&E effort will be a valuable asset to all GRS sites by providing designs, analyses, and procurement specifications for commonly used buildings and facilities.

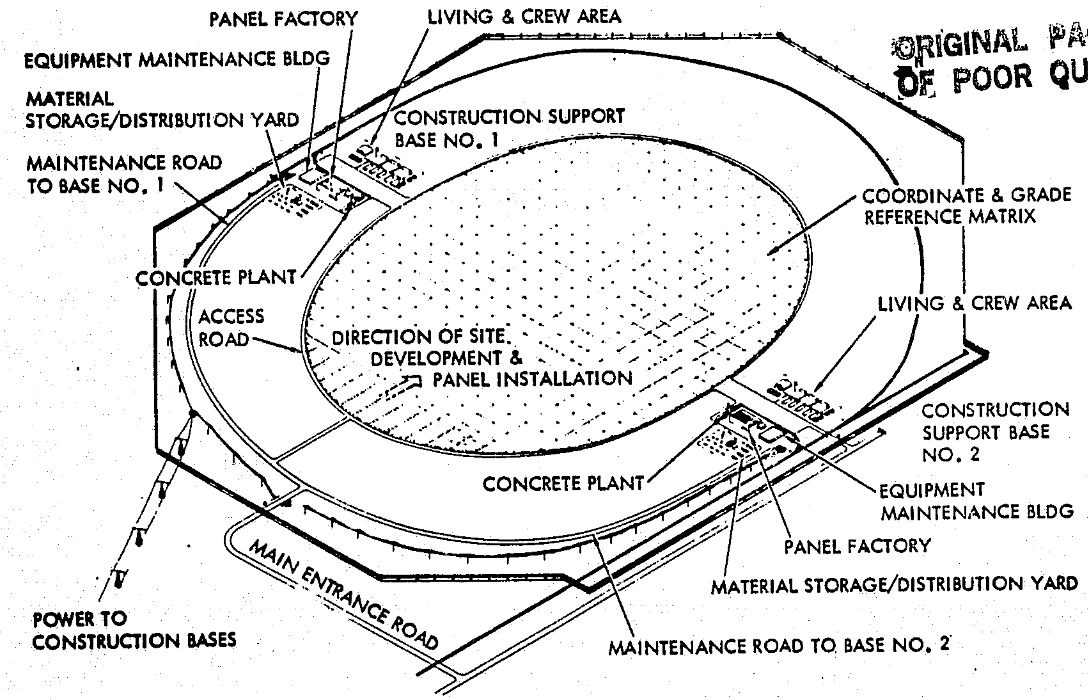

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Figure 1.4-3. Support Facilities

Clearing and leveling operations will occur at a number of locations within the panel farm perimeter. These operations consist of tree removal (if required), grading, and leveling the terrain to acceptable slope angles, and removing excess dirt. Sixteen areas of the ellipse would be cleared and leveled simultaneously. Bulldozers will make the initial cut, scrapers will grade to more precise requirements, and an estimate was made of one crew of 13 men

to grade eight acres per day. The crew and equipment required to prepare a 35,000 acre site was established based on a single shift that would level 130 acres per day to meet a nine month schedule.

Costs developed for the site and facilities are divided into the elements of land, site preparation, roads and fence, utilities, buildings and facilities, maintenance equipment, lightning protection, and DDT&E. Basic design parameters used in this costing are presented in Table 1.4-4. The DDT&E, investment, and operations cost established for each element are tabulated as follows:

Table 1.4-4. Site and Facilities Requirements

ITEM	UNIT PARAMETER
LAND/FENCING	35,000 ACRES
GRADING/LEVELING	HEAVY EQUIPMENT/CREW SIZE
PREPARATION	SURVEY, EIR, PERMITS, A&E PLANNING
UTILITIES	WATER, ELECTRICITY, GAS, SEWAGE
ROADS/RAILS	ROADS 35 MILES; RAILS 45 MILES
FACILITIES	CONVERSION STATION, MONITOR & CONTROL, MAINTENANCE/STORAGE
DRAINAGE	6" GRAVEL FOR COMBINATION ACCESS-WAY & DRAINAGE BETWEEN PANEL ROWS
LIGHTNING PROTECTION	TBD

Table 1.4.1.1 Land and Preparation (Land - 1.4.1.1.1, Preparation - 1.4.1.1.2)

Table 1.4.1.2 Roads and Rences (Rails & Roads - 1.4.1.2.1, Fencing - 1.4.1.2.2)

Table 1.4.1.3 Utilities

Table 1.4.1.4 Buildings and Facilities (Storage/Maintenance - 1.4.1.4.1, Converter Station - 1.4.1.4.2)

Table 1.4.1.5 Maintenance Equipment

Table 1.4.1.6 Lightning Protection System

Table 1.4.1.7 Site & Facilities DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.1.1 LAND

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	35000.0000	TF=	1.000000	CDCER=	0.0
M=	35000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.001000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	ACRES	SUM TO 1.4.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			35.000
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			35.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			35.000
CIPS=CTB*Z4/Z2			35.000
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.1.2 LAND PREPARATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	35000.0000	TF=	1.000000	CDCER=	0.0
M=	35000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.002007
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	ACRES	SUM TO 1.4.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			70.245
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.341
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			64.119
CIPS=CTB*Z4/Z2			64.119
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.2.1 RAILS AND ROADS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	73.710007
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	73.710
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	73.710
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	73.710
CIPS=CTB*Z4/Z2	73.710
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.2.2 FENCING

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	42671.0000	TF=	1.000000	CDCER=	0.0
M=	42671.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000011
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES M SUM TO 1.4.1.2 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.469
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.470
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.428
CIPS=CTB*Z4/Z2		0.428
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.3 UTILITIES

INPUT PARAMETERS

T=	1.000000	TF=	1.000000		
M=	1.000000	O&M=	0.0		
CF=	1.000000	Z1=	1.000000		
PHI=	1.000000	Z2=	60.000000		
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

INPUT COEFFICIENTS

CDCER=	0.0
CDEXP=	0.0
CICER=	0.200000
CIEXP=	1.000000

CALCULATED VALUES SET SUM TO 1.4.1 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.200
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.200
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.200
CIPS=CTB*Z4/Z2	0.200
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.4.1 STORAGE,MAINTENANCE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	1.300000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES $	SUM TO 1.4.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		1.300
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		1.300
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		1.300
CIPS=CTB*Z4/Z2		1.300
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.4.2 CONV. STA. & MONITOR/CONTROL FAC.

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	21290.0000	TF=	1.000000	CDCER=	0.0
M=	21290.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000478
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.4.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			10.177
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			10.177
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			10.177
CIPS=CTB*Z4/Z2			10.177
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.5 MAINTENANCE EQPT.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	4.000000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.050000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	$	SUM TO 1.4.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			4.000
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			4.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			4.000
CIPS=CTB*Z4/Z2			4.000
CPCI =CTB X R			0.200
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.6 LIGHTNING PROTECTION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	$	SUM TO 1.4.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M		0.0	
E =1.0 + LOG(PHI) / LOG(2.0)		0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.7 SITE & FACILITIES DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	1.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES $ SUM TO 1.4.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	1.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	0.0
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1.4.2 RECTENNA SUPPORT STRUCTURE

The rectenna farm area of 102.1 $(km)^2$ is covered by 580,500 panels that have a total mW intercept area of 79.53 $(km)^2$. Each panel (9.33 m × 14.69 m) is tilted at an angle of 40° to the horizontal and is mounted on two continuous ribbons of concrete as shown in Figure 1.4-4. The procurement, fabrication, assembly and installation of the steel rectenna support structure, and the supporting foundation placement are costed in this section and represent the results of consultation and discussions with industrial/construction contacts.

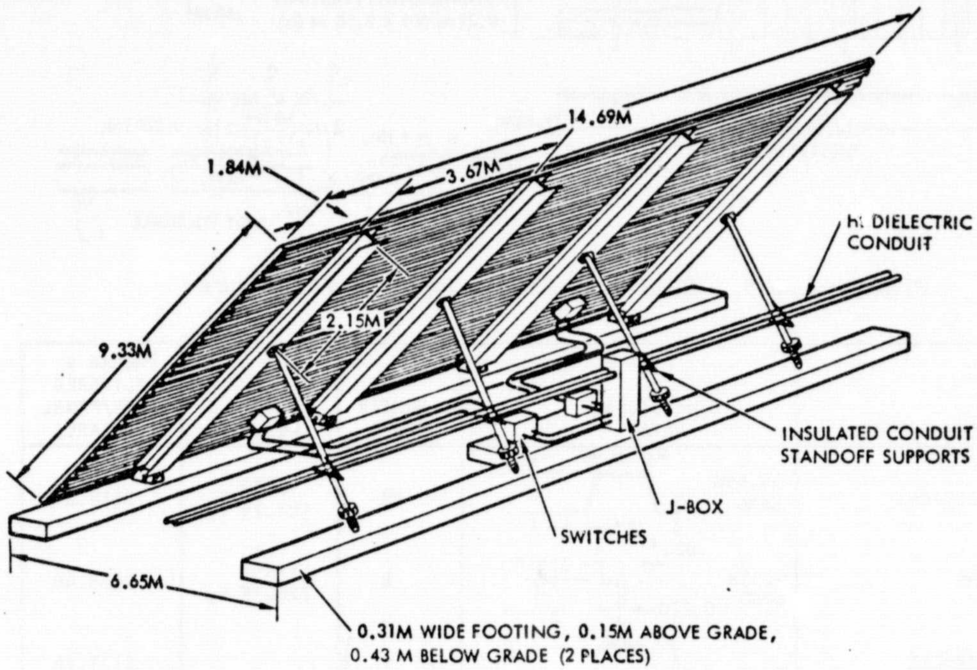

Figure 1.4-4. Panel Installation

1.4.2.1 PANEL STRUCTURE

The rectenna panel structure is comprised of four standard size eight-inch (wide flange) I beams, supporting tube braces, and 18 hat-shaped sections for the mounting of the power collection electronic elements. Tube braces, steel cast fittings and attachment hardware are used to support the panel on the continuous footing as shown in Figure 1.4-5.

A detail analysis of the support structure was completed to identify the amount of material needed; fabrication, operations, assembly, and installation requirements; plus an estimate of manpower and equipments needed to produce the average daily production of 2150 panels over the nine month period. The cost of material for a rectenna panel is shown in 1.4-6.

The rectenna panel hat section serves as a mounting surface for the laminated-copper-clad mylar array elements. (See section 1.4.3, Power Collection). Adhesives will be used to mount the elements to the structure to

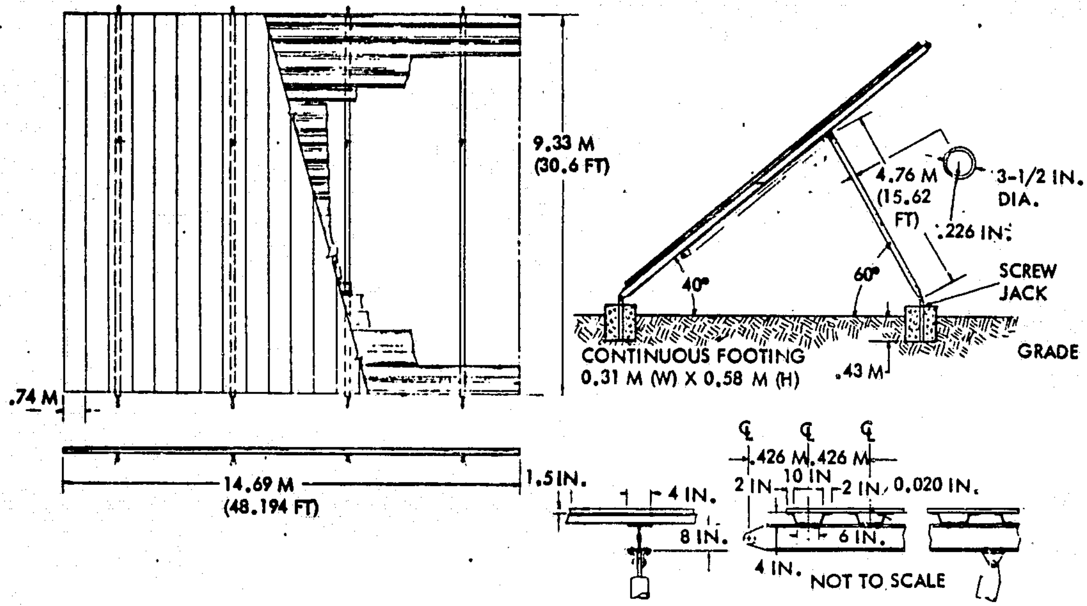

Figure 1.4-5. Rectenna Array Support Structure

ITEM/DESCRIPTION	DIMENSIONAL DATA	NUMBER REQ'D	TOTAL WEIGHT	PREFAB & DELIVERED COST/PANEL (DOLLARS)
HAT SECTIONS	14.69M LONG; 6"; 4"; 2"; .020"	18	1288# 584.25 kg	$618.24
I-BEAMS	9.33M LONG; 3.94"; 0.170; 7.90"; 0.204	4	1589# 720.75 kg	$508.48
TUBE BRACES	4.76M LONG; 0.226"; 3.50"	4	1104# 500.75 kg	$773.76
HARDWARE FITTINGS & WELDING ROD		4 SETS		
RETURNED SCRAP ALLOWANCE			-307# -139 kg	$30.70
TOTAL MATERIAL PER PANEL			3674# 1666.75 kg	$1869.78

Figure 1.4-6. Rectenna Panel Support Structure

provide continuous support and added strength with a minimum of localized panel deflection.

The basic hat section is formed at the rectenna site from 0.020" galvanized steel sheet stock by processing through a set of forming rollers in a continuous manner. The forming machine (Yoder mill) accommodates widths of rolled mill stock sufficient to produce the finished hat sections ready for assembly to the I-beams.

Four standard wide-flange 8-inch galvanized steel I-beams are required in lengths of 9.33 m for each rectenna panel. This material will be delivered to the site in precut lengths for hole punching and the addition of brackets/machined castings for the support braces and panel mounting.

Four 3.5" diameter tube braces of galvanized steel are cut to a length of 4.76 m and preassembled to the fittings/hardware. Anchors, brackets, clips, hangers, etc., are fabricated or cast of carbon steel material and galvanized prior to machining at the site. All these items are scheduled to combine with the hat sections and I-beams at a centralized facility for assembly. A concept for such a facility is shown in Figure 1.4-7. The factory has multiple assembly lines where each line has a materials feed section, steel assembly facilities, electron ics assembly and checkout section. It was assumed that one line using automated procedures could assemble and checkout a panel in 40 minutes. On this basis, seventy-two assembly lines operating 20 hours per day, seven days a week are required to produce 580,500 panels in the allocated 270 days. Eight additional requirements are summarized in the lower left of the figure.

After the panels have been checked, they are placed on an overhead conveying system and transported to loading stalls, where they are assembled into 9-panel magazines and loaded on specially designed trucks for delivery to the point of installation.

Specialized equipment is required to deliver the panels from the factory to the installation point and to install them because of their large dimensions. After consultation with industrial sources on large equipment handling, a concept for a specialized machine was developed (Figure 1.4-8). The front and rear wheel pairs are each steerable as a unit and have provisions for height adjustment. The panels are transferred in magazines and lifted by means of fixtures mounted in vertical rails. They can be translated laterally and longitudinally for final positioning before attachment to the footings.

1.4.2.2 TRENCHING AND CONCRETE FOOTINGS

A trade-off which considered eight individual footings versus continuous footings was made. A maximum wind force of 90 m/hr was assumed. It was determined that the amount of concrete required for either approach was essentially the same, but that the continuous footing concept was easier to install and required fewer operations and less capital equipment.

Each panel is secured to the footings at eight locations by fixtures which are imbedded in the concrete during the pouring operation. Mounting attachments which provide for longitudinal and lateral adjustment are secured to the fittings. Screw jacks on each of the rear attach points provide for panel adjustment and alignment.

The footings of continuous concrete are 0.43 meters deep, 0.31 meters wide, and project 0.15 meters above ground level. Two footings are excavated simultaneously by trenchers which feed the removed dirt into a truck. Approximately 17×10^6 meters of trenches must be excavated. To accomplish this, 38 trenchers are required, each trencher excavating 90 meters per hour.

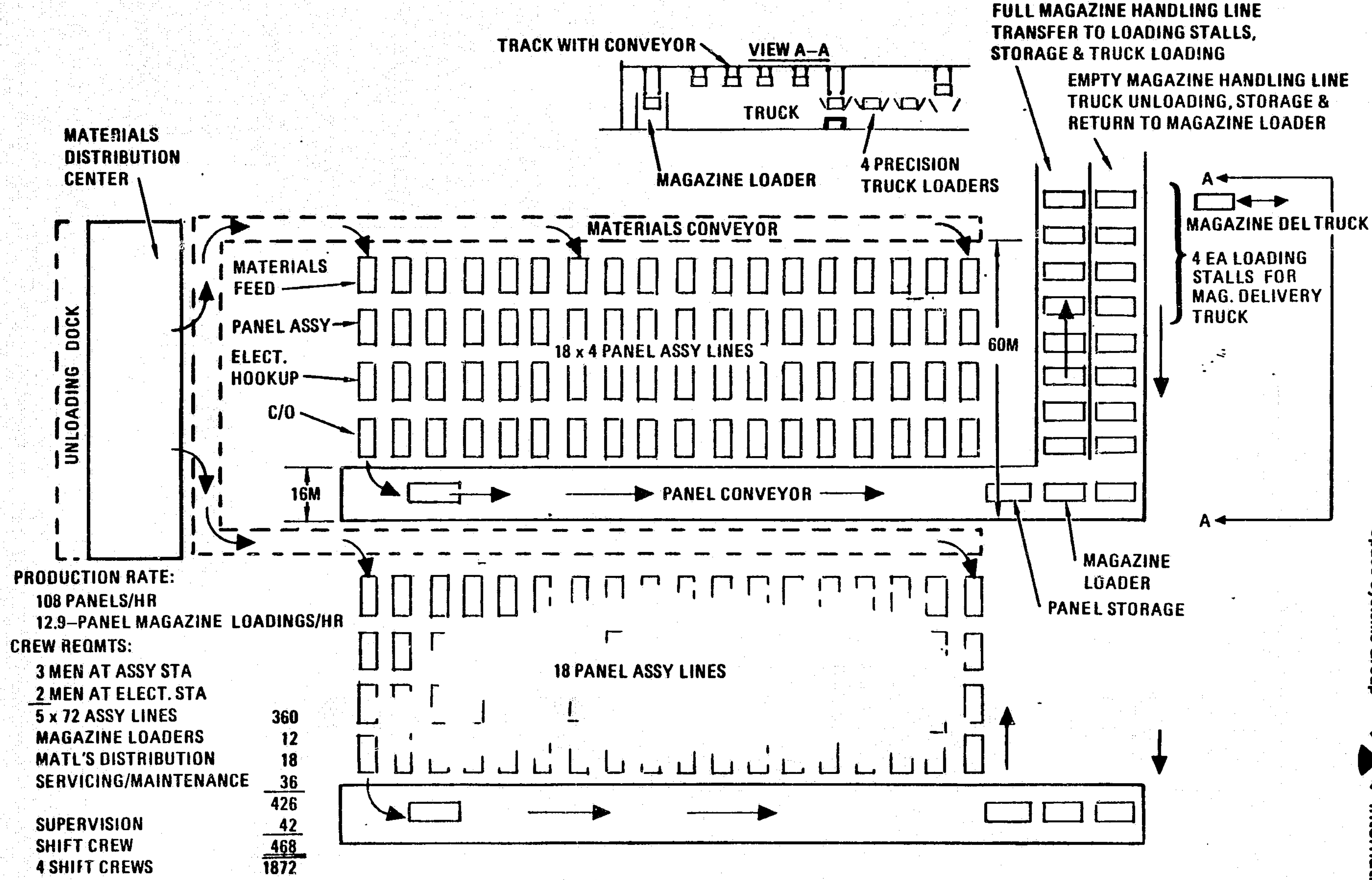

Figure 1.4-7. Central Panel Factory

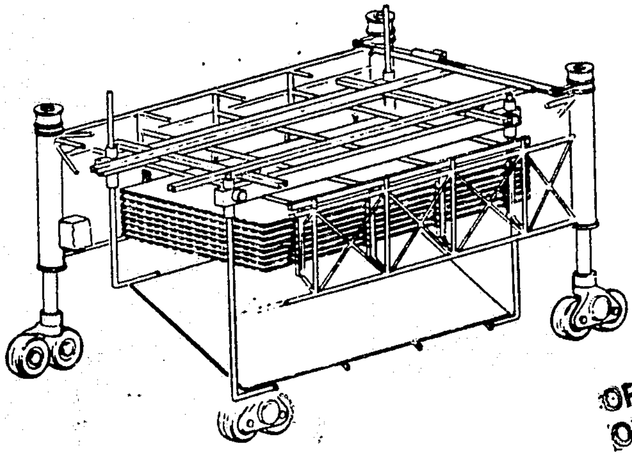

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Figure 1.4-8. Panel Loading Sequence

Table 1.4-5 summarizes crew and equipment requirements compatible with the nine month schedule to prepare 1088 panel rows per rectenna.

Table 1.4-5. Concrete Footing Equipment/Crew

ITEM/DESCRIPTION	SITE CONSTRUCTION QUANTITY	1977 UNIT PRICE (DOLLARS)	TOTAL COST
TRENCHERS - JW-2	38	$70,000	$2,660,000
DUMP TRUCKS - 992C	26	$350,000	$9,100,000
CONCRETE DELIVERY VEHICLES - 10 C.Y.	190	$50,000	$9,500,000
CONCRETE FORMING MACHINES	10	$60,000	$600,000
CONCRETE CENTRAL MIX PAVING PLANTS	2	$250,000	$500,000
TOTAL COST			$22,360,000
TRENCHING & CONCRETE CREW PERSONNEL	1480		

Each rectenna panel will be mounted and aligned on 6.8 cu yds of concrete placed by concrete formers such as those commonly used in freeway divider construction. The formers extrude a shaped ribbon at rates of 6 meters per minute. Reinforcing steel and panel attach fittings are inserted as the concrete is vibrated during the extrusion process. Concrete footing requirements for the rectenna panels are shown in Table 1.4-6.

Table 1.4-6. Concrete Footing Requirements

ITEM/DESCRIPTION	1977 $ (MILL PRICE DELIVERED)	INGREDIENTS FOR 6.8 CU.YDS.	MATERIAL COST DELIVERED (1977 DOLLARS)
CEMENT (5 SACK) (94# SACK)	$42/TON	3196#	$67.12
SAND	$4.51/TON	9520#	$21.47
ROCK 1"-1½"	$4.39/TON	12444#	$27.31
WATER	-	2040#	Ø
REINFORCING STEEL - #4	$0.10/LB	64#	$6.44
TOTAL/PANEL		27264#	$122.34
DELIVERED 1977 MILL PRICES PER ENGINEERING NEWS RECORD (ENR) - McGRAW HILL, AN INDUSTRY PUBLICATION			

1.4.2.3 COST ESTIMATES

DDT&E, investment, construction/installation, and operations costs of the rectenna support structures (less electronic elements) and the concrete footings are identified in the following tables:

- Table 1.4.2.1.1 Hat Sections
- Table 1.4.2.1.2 Wide Flanges
- Table 1.4.2.1.3 Tube Braces & Hardware
- Table 1.4.2.1.4 Assembly & Installation
- Table 1.4.2.2.1 Footing Concrete & Rebar
- Table 1.4.2.2.2 Machinery & Equipment
- Table 1.4.2.2.3 Construction Operations
- Table 1.4.2.3 Support Structure DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.1.1 HAT SECTIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000619
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	PANEL	SUM TO 1.4.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		580500.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			359.228
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			359.224
CIPS=CTB*Z4/Z2			359.224
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS
EACH PANEL USES 18 HAT SECTIONS TOTALING 584.25 KG (1288LBS)
WITH COST ESTIMATE(US$) OF
$1.058/KG ($.48/LB).

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.1.2 WIDE FLANGES

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000508
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES PANEL SUM TO 1.4.2.1 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.001
#RM =T / M	580500.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	295.173
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	295.170
CIPS=CTB*Z4/Z2	295.170
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.1.3 TUBE BRACES & HARDWARE

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000743
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	PANEL	SUM TO 1.4.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		580500.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			431.346
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			431.343
CIPS=CTB*Z4/Z2			431.343
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

INCLUDES 4 TUBE BRACES 4.76M LONG,
FRONT & REAR CLEVIS FITTINGS,CAST MOUNTINGS,WELD ROD,
AND PROVIDES FOR OVERALL SCRAP ALLOWANCES.

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.1.4 ASSEMBLY & INSTALLATION

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000		CDCER=	0.0
M=	1.000000	O&M=	0.0		CDEXP=	0.0
CF=	1.000000	Z1=	1.000000		CICER=	0.001052
PHI=	1.000000	Z2=	60.000000		CIEXP=	1.000000
R=	0.0	Z3=	60.000000			
DF=	1.000000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES	PANEL	SUM TO 1.4.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		580500.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			610.762
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			610.757
CIPS=CTB*Z4/Z2			610.756
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.2.1 FOOTING CONCRETE & RE-BAR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000122
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	PANEL	SUM TO 1.4.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.000
#RM =T / M		580500.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.821
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			70.820
CIPS=CTB*Z4/Z2			70.820
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

CONCRETE ESTIMATED AT 6.8 CU YDS OF 5 SACK CEMENT.
MIX 3196 LBS CEMENT, 9520 LBS SAND,
12444 LBS 1-1.5 INCH ROCK.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.2.2 MACHINGERY & EQUIPMENT

INPUT PARAMETERS | | | | INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.447200	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	22.360001
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.003333	Z3=	8.000000		
DF=	1.000000	Z4=	2.000000	Z5=	0.0

CALCULATED VALUES	SET	SUM TO 1.4.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			22.360
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			22.360
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			22.360
CIPS=CTB*Z4/Z2			0.745
CRCI =CTB X R			0.075
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.447

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.2.3 CONSTRUCTION OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	399600.000	TF=	1.000000	CDCER=	0.0
M=	399600.000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000150
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	MANDAYS	SUM TO 1.4.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			59.940
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			59.940
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			59.940
CIPS=CTB*Z4/Z2			59.940
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.3 SUPPORT STRUCTURE DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	2.000000
M=	1.000000	O&M=	0.0	CDEXP=	0.300000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	2.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	0.0
CRCI =CTB X R	0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1.4.3 POWER COLLECTION

This element of the GRS includes the rectenna array elements associated with the actual reception and rectification of the microwave radiation. These elements are in series and parallel as required to deliver the line output voltage and current. Also included are those components that accept the dc power from the array elements and route, control, convert, and switch this power for delivery to the power conversion stations of the grid interface.

The rectifier assembly consists of a GaAs diode and input/output filters. The outputs of the rectifier circuit are series connected to output 40+ kV (Figure 1.4-9). The regulation assembly accepts the voltage from the series connected rectenna diodes and adjusts the voltage output to the power distribution feeders to a value consistent with positive current flow. The rectenna array elements are 0.735×9.33 m in size and 20 elements are combined per panel with diode circuitry equivalent to the mW density pattern. A total of 735 diodes or diode equivalents are required per average panel with a rectenna total of 330×10^6 diodes as shown in Figure 1.4-10.

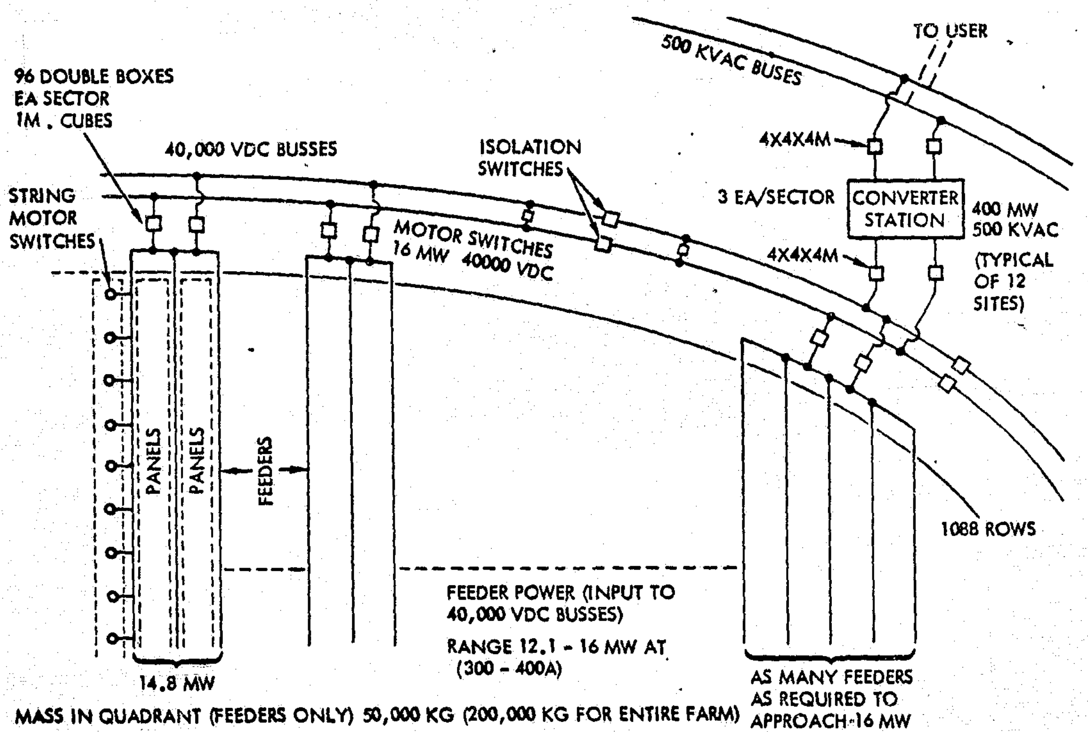

Figure 1.4-9. Rectenna Schematic Block Diagram - Preliminary

The electronic array element of the antenna is a multilayered copper/dielectric sandwich panel material. Resource/mass projections are identified in Table 1.4-7. These calculations were based on the array cross section and panel requirements shown in Figure 1.4-11. Costs were determined from

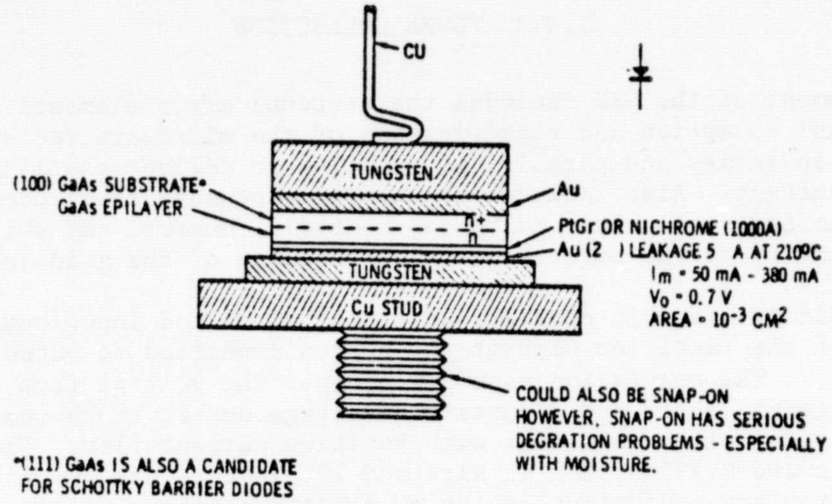

Figure 1.4-10. Diode Concept

Table 1.4-7. Resource Requirements Rectenna Dipole - Bow-Tie - Panel Array Elements

580,500 RECTENNA PANELS		
• DIELECTRIC		
PLASTIC COMPOUND—3.5 LB/FT^3, 0.4375 LB/FT^2 x 856.4 x 10^6 FT^2	-	374.68 x 10^6 LB
• MYLAR		
0.001-IN. THICKNESS AT 87.36 LB/FT^3, 0.02913 LB/FT^2 x 856.4 x 10^6 FT^2	-	24.95 x 10^6 LB
• COPPER		
0.0039 THICKNESS AT 556.6 LB/FT^3, 0.118753 LB/FT^2 x 856.4 x 10^6 FT^2	-	101.70 x 10^6 LB
• DIODES		
1 OZ. PER 426.67 x 10^6 DIODES OR EQUIV.	-	26.67 x 10^6 LB
TOTAL		528 x 10^6 LB
		909.6 LB/PANEL 412.6 KG/PANEL

estimating guides/industrial contacts and combined with the cost of switches and regulators needed at each panel to provide a total cost estimate of $1942 for the antenna array elements.

The power collection and distribution system consists of all field feeders (collectors), supporting switchgear, 40 kV dc buses to the power converters, and the towers/footings needed to support the transmission lines. Approximately 330,000 switchgears, 10^7 meters of feeder cables, miscellaneous junction boxes, etc., must be delivered and installed at the panel sites. Tractor/trailer trucks are used for this purpose and proceed through the panel rows,

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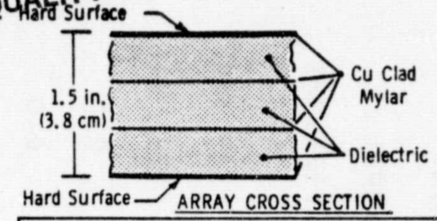

- 20 ARRAY ELEMENTS/PANEL
- 1475 FT^2 (137 M^2) PER PANEL
- 1990 TECHNOLOGY
- 1977 PRICES

• TOTAL PANEL AREA	9.33 M x 14.69 M x 580,500 PANELS (30.61 FT x 48.19 FT x 580,500 PANELS	• 79.56 x 10^6 M^2 • 856.4 x 10^6 FT^2)
• DIELECTRIC	0.4375 LB/FT^2 x 856.4 x 10^6 FT^2 @ \$0.872/LB	• \$326.72 x 10^6
• MYLAR/SURFACE	4 LAYERS x 856.4 x 10^6 FT^2 @ \$0.10 FT^2	• \$342.56 x 10^6
• COPPER (PROCESSED/BONDED)	65% COVERAGE x 856.4 x 10^6 FT^2 @ \$0.15/FT^2	• \$ 83.50 x 10^6
• DIODES/EQUIVALENTS/WIRE	426.67 x 10^6 DIODES @ \$0.10 EA.	• \$ 42.67 x 10^6
• BONDING	6 SURFACES x 856.4 x 10^6 FT^2 @ \$0.0262/FT^2	• \$134.63 x 10^6
	TOTAL	• \$930.08 x 10^6 (\$1602.20/PANEL)

Figure 1.4-11. Rectenna Dipole - Bow-Tie - Panel Array Elements

delivering material at each panel. Additional trucks with reels playout the feeders, which then are installed in conduits and spliced to panel connections by the electrical installation crew. Contacts with a utility company indicate a requirement of 8 manhours to hookup one panel. On this basis, the manpower and equipment projections were established for a 20 hour 7 day week.

Equipment for electrical hookup and checkout of completed panels was calculated on the basis of acquisition cost prorated over the service life and utilization period at a particular site. Total crew requirements of 4196 personnel and the schedule period were the basis of calculating man-day requirements of 755,280. The amortized cost of equipment and labor were combined for the total cost factor.

DDT&E power collection costs are associated with the design and verification of bow-tie electronic panels/bonding processes, connectors, and large switchgear to optimize the voltage/current ratios and element/wiring configuration. Cost estimates are provided in the following areas:

Table 1.4.3.1 Antenna Array Elements

Table 1.4.3.2 Power Distribution System

Table 1.4.3.3 Installation and Checkout

Table 1.4.3.4 Power Collection DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.3.1 ANTENNA ARRAY ELEMENTS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.001942
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES PANEL SUM TO 1.4.3		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.002
#RM =T / M	580500.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		1127.331
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		1127.322
CIPS=CTB*Z4/Z2		1127.321
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.3.2 POWER DISTRIBUTION SYSTEM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000120
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES PANEL SUM TO 1.4.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.000
#RM =T / M	580500.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	69.660
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	69.659
CIPS=CTB*Z4/Z2	69.659
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.3.3 INSTALLATION & CHECKOUT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	781100.000	TF=	1.000000	CDCER=	0.0
M=	4340.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000200
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	MANDAYS	SUM TO 1.4.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.868
#RM =T / M		179.977	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			156.220
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			156.220
CIPS=CTB*Z4/Z2			156.220
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.3.4 POWER COLLECTION-DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	3.000000
M=	1.000000	O&M=	0.0	CDEXP=	0.300000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SET	SUM TO 1.4.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

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1.4.4 CONTROL

The telemetry, tracking, communications, monitoring of microwave beam characteristics, computing phase corrections, and the equipment needed to provide frequency standard signals for the satellite are included in this section. This hardware will be used to monitor and control the satellite from the ground.

The following monitor and control functions are performed:

1. Tracking, using ground-based radars to monitor the orbital stability of the satellite.

2. Beam monitoring and control, using ground equipment for adaptive or command control of the satellite microwave beam.

3. Data management, using equipment required to analyze signals and data from the satellite and ground-based systems to compute control signals and corrective data to maintain safe and optimum performance.

4. Communications, using equipment required to maintain communications between the ground station and the SPS satellite. Included are the communications with the crew, and telemetry and command equipment not included in the beam monitoring and control assembly.

At this time, the cost effort is divided into the three categories of control center equipment, beam control electronics, and DDT&E. Two sets of full-up IBM 370, or equivalents, a complete display center, and a manned control room are envisioned as basic elements of the control center. Beam control electronics would consist of control sensors and dual frequency transmitters. The overall DDT&E and hardware costs were projected by engineering. The exacting requirement of this rectenna operation will require further study in future contract activity to define the technical and performance standards. It should also be noted that system and operational requirements are needed to define adequate software/programming considerations.

Cost estimates are presented as follows:

Table 1.4.4.1 Control Center Equipment

Table 1.4.4.2 Control Electronics

Table 1.4.4.3 Control DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.4.1 CONTROL CENTER EQUIPMENT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	15.000000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	15.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	15.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	15.000
CIPS=CTB*Z4/Z2	15.000
CRCI =CTB X R	0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.4.2 CONTROL ELECTRONICS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	60.000000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5 =	0.0

CALCULATED VALUES SET SUM TO 1.4.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	60.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	60.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	60.000
CIPS=CTB*Z4/Z2	60.000
CRCI =CTB X R	0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.4.3 CONTROL DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	10.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	10.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	0.0
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

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1.4.5 GRID INTERFACE

This element includes the power conversion equipment that receives electrical power from the power collection system and conditions/converts it to a high voltage dc or ac power acceptable for input into the national power grid.

The converter stations accept 40 kV dc power and output 500 kV ac or dc. The concept utilizes a solid-state inversion/step-up concept typified by an existing dc - ac conversion station located in Sylmar, California. Although specific design details of this system await clarification in a future study effort, an analysis and cost estimate was prepared as shown in Table 1.4-8. The CER for DDT&E were derived from cost estimates in the "Technical Study Report on Pacific Northwest-Southwest dc inter-tie," prepared by the Bonneville Power Administration in February, 1976. This DDT&E estimate was based on six cost quotations which Bonneville received on a 1.44 GW and a 2.20 inter-tie. The total cost for the 1.44 GW terminal ($156.7 $\bar{M}$) was allocated as 30% DDT&E and 70% ICI. This judgment was based on the assumption that most of the facility will be a standard design.

Table 1.4-8. Grid Interface (WBS 1.4.5)

ITEM DESCRIPTION	SPECIFICATION	GRS QUANTITY	PROJECTED UNIT COST	TOTAL (1977 $)
CONVERTER STATIONS	400 mW 500 kV ac or kV dc	12 EA.	$\$10\times10^6$	$\$120\times10^6$
ISOLATION SWITCH-GEAR	4×4×4 m	24 EA	$400,000 EA	$\$0.96\times10^6$
FILTER YARDS		12	$100,000 EA	$\$1.2\times10^6$
INTERCONNECT TOWERS & FOUNDATION	500 kV ac TOWERS	90 EA		$\$12.741\times10^6$
INTERCONNECT TRANSMISSION CABLE		12 LINES	$90,000/MI	$\$10.789\times10^6$
TOTAL/GRS				$\$145.69\times10^6$

Cost estimates are presented in Table 1.4.5.1 on electrical equipment and in Table 1.4.5.2 on DDT&E.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.5.1 ELECTRICAL EQUIPMENT

INPUT PARAMFTERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	145.690002
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.5		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		145.690
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		145.690
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		145.690
CIPS=CTB*Z4/Z2		145.690
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.5.2 GRID INTERFACE-DDT&E

INPUT PARAMETERS

T=	5.000000	TF=	1.000000		
M=	5.000000	O&M=	0.0		
CF=	1.000000	Z1=	1.000000		
PHI=	1.000000	Z2=	60.000000		
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

INPUT COEFFICIENTS

CDCER=	37.714996
CDEXP=	0.604000
CICER=	0.0
CIEXP=	0.0

CALCULATED VALUES GW SUM TO 1.4.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	99.699
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	0.0
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1.4.6 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground receiving station. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground station operation and maintenance.

Operations and maintenance personnel required after IOC are identified as a 300 personnel staff to provide a 24 hour cperation, maintenance/repair, security, and administrative support (Table 1.4-9). A cost estimate for maintenance material (expendables, trucks, and equipment); standby auxiliary power; and test/support equipment is also identified in the table.

Table 1.4-9. Operations Requirements

ITEM	SHIFT	NO.	TOTAL	1977 DOLLARS
• OPERATIONS & MAINTENANCE PERSONNEL				
COMMAND & CONTROL CENTER (PERSONNEL + SUPERVISORY)	1	30		
	2	30		
	3	20	80	
CONVERTER STATION (TOTAL FOR 12 STATIONS)	1	36		
	2	36		
	3	36	108	
24-HOUR MAINTENANCE, REPAIR, SECURITY, & G&A/SUPPORT		112	112	
			300	
• MAINTENANCE MATERIAL				$\$13.13 \times 10^6$
EXPENDABLES, TRUCKS, EQUIP., UTILITIES, TEST/SUPPORT EQUIP.				

Cost estimates are shown in Table 1.4.6.1 for operations and maintenance personnel and in Table 1.4.6.2 for maintenance material.

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ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.6.1 OPER. & MAINT. PERSONNEL

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	300.000000	TF=	1.000000			CDCER=	0.0
M=	300.000000	O&M=	64.800003			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.0
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.0
R=	0.0	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES MAN-DAYS	SUM TO 1.4.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		64.800

COMMENTS

360 DAYS/YR * 3 SHIFTS/DAY * 300 MANDAYS/SHIFT * $200/MANDAY

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.6.2 MAINT. MATERIAL

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	13.130000	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	0.0
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	13.130

COMMENTS

1.5 MANAGEMENT AND INTEGRATION

This element includes all efforts and material required for management and integration functions at the systems level and program level. It encompasses the following functions:

1. Program Administration
2. Program Planning and Control
3. Contracts Administration
4. Engineering Management
5. Manufacturing Management
6. Support Management
7. Quality Assurance Management
8. Configuration Management
9. Data Management
10. Systems Engineering and Integration.

This element sums all of the direct effort required to provide management control including planning, organizing, directing, and coordinating the project to ensure that overall project objectives are accomplished. These efforts overlay the functional work areas (e.g., engineering, manufacturing, etc.) and assure that they are properly integrated. This element also includes the efforts required in the coordination, gathering, and dissemination of management information. Also included are the engineering efforts related to the establishment and maintenance of a technical baseline for a system by generation of system configuration parameters, criteria, and requirements. It includes requirements analysis and integration, system definition, system test definition, interfaces, safety, reliability, and maintainability. It also includes those efforts required to monitor the system development and operations to ensure that the design conforms to the baseline specifications.

The management and integration function for DDT&E, TFU :ICI, RCI and O&M are estimated at a cost equal to 5% of the corresponding total dollar estimates for WBS elements 1.1 through 1.4 within each area. Table 1.5 presents this tabulation.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION
TABLE 1.5 MANAGEMENT AND INTEGRATION

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES 5% * ALL SUM TO 1 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	1392.463
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#RM =T / M	0.0
E =1.0 + LOG(PHI) / LOG(2.0)	0.0
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	2151.918
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	600.679
CRCI =CTB X R	18.815
CO&M = O&M OR CTB*Z5/Z2/ENYR	8.561

COMMENTS
DDT&E,TFU,ICI,RCI, AND O&M ARE
CALCULATED AT 5% OF CORRESPONDING TOTALS
FOR WBS 1.1 THROUGH 1.4

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1.6 MASS CONTINGENCY

A cost contingency has been added to the SPS Program to provide for potential growth due to increased weight as a result of design/development activities that would affect the procurement of systems during any phase of the program. This allowance is costed as a 15% bottom line contingency to the DDT&E, TFU, ICI, RCI and O&M elements of the program. Table 1.6 reflects the total amounts in each of these areas based on the totals of items 1.1, 1.2, and 1.3.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.6 MASS CONTINGENCY

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	0.0	IF=	1.000000		CDCER=	0.0
M=	0.0	O&M=	0.0		CDEXP=	0.0
CF=	0.0	Z1=	1.000000		CICER=	0.0
PHI=	1.000000	Z2=	60.000000		CIEXP=	0.0
R=	0.0	Z3=	60.000000			
DF=	1.000000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES	SUM TO 1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		4160.031
CERM=CICER X (M)XX(CIEXP) X CF X IF		0.0
#RM =1 / M		0.0
E =1.0 + LOG(PHI) / LOG(2.0)		0.0
CTFU=(CERM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		5912.945
CTB =((CERM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		1263.413
CRCI =CTB X R		56.405
CO&M = O&M OR CTB*Z5/Z2/ENYR		13.927

COMMENTS
A 25% MASS CONTINGENCY IS COSTED
AS A 15% COST CONTINGENCY ON 1.1, 1.2, 1.3

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